US Army Corps
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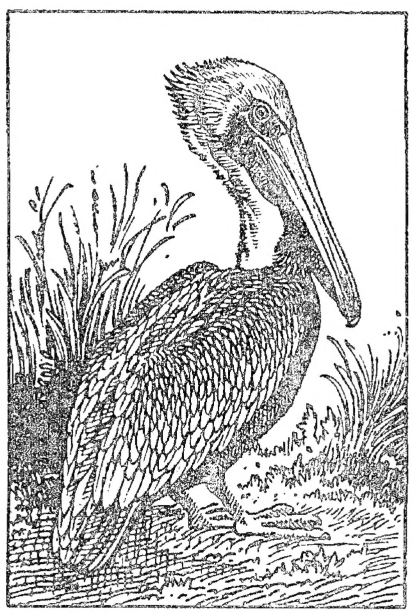
Wetlands Research Program Technical Report WRP-SM-17

Avian Responses to Chemically and Physically Manipulated Cattail Stands in a Northern Prairie Marsh

by Mark J. Humpert, Daniel E. Hubbard, and Kent C. Jensen



December 1995 – Final Report

The following two letters used as part of the number designating technical reports of research published under the Wetlands Research Program identify the area under which the report was prepared:

	Task		Task
CP	Critical Processes	RE	Restoration & Establishment
DE	Delineation & Evaluation	SM	Stewardship & Management

Wetlands Research Program

Technical Report WRP-SM-17
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Avian Responses to Chemically and Physically Manipulated Cattail Stands in a Northern Prairie Marsh

by Mark J. Humpert, Daniel E. Hubbard

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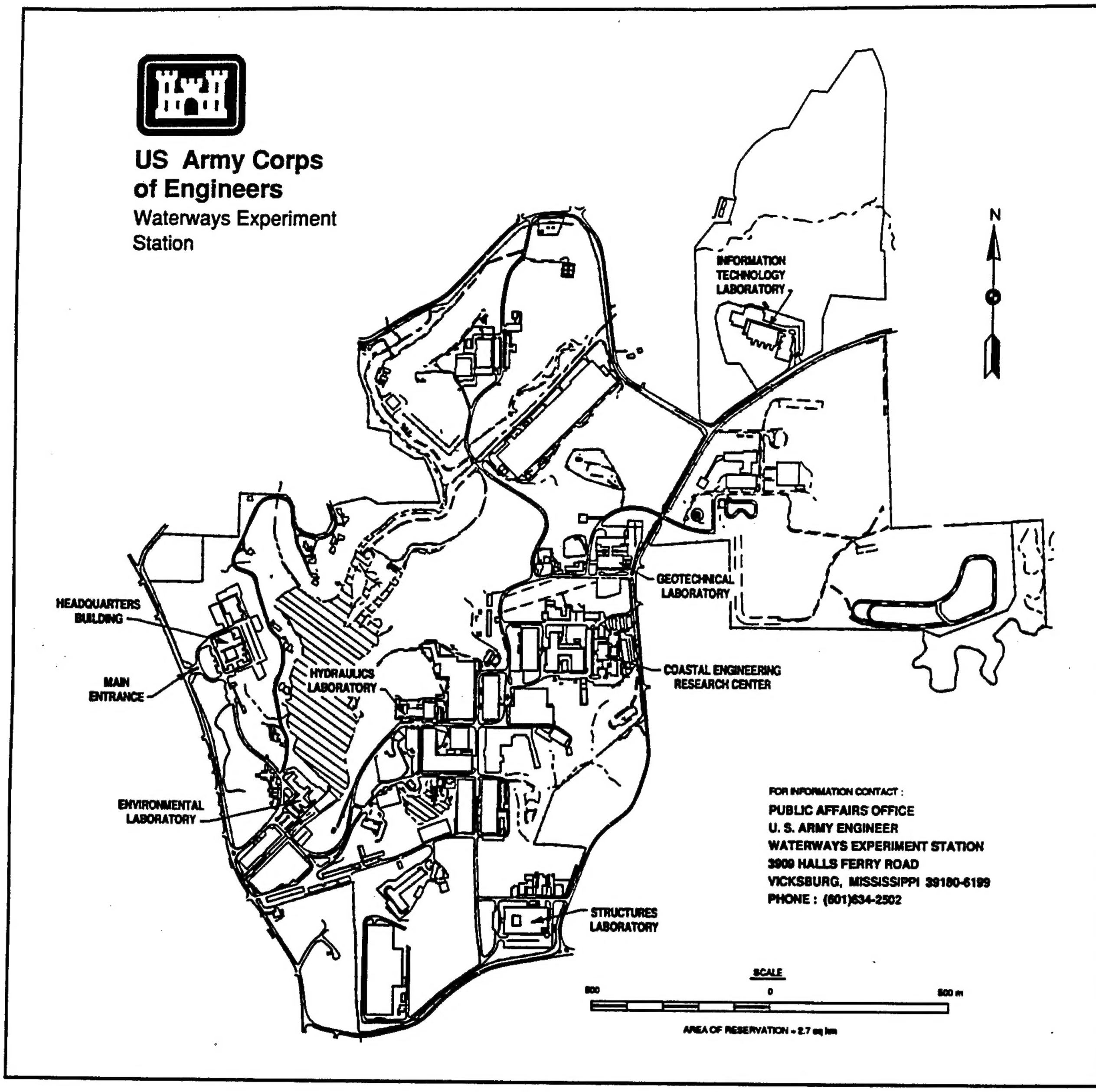
Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000



Waterways Experiment Station Cataloging-in-Publication Data

Humpert, Mark J.

Avian responses to chemically and physically manipulated cattail stands in a northern prairie marsh / by Mark J. Humpert, Daniel E. Hubbard, Kent C. Jensen ; prepared for U.S. Army Corps of Engineers.

68 p. : ill. ; 28 cm. -- (Technical report ; WRP-SM-17) (Wetlands Research Program technical report ; WRP-SM-17)

Includes bibliographic references.

1. Wetland flora. 2. Habitat ecology -- Prairie Pothole Region. 3. Waterfowl. I. Hubbard, Daniel E. II. Jensen, Kent Charles, 1955- III. United States. Army. Corps of Engineers. IV. U.S. Army Engineer Waterways Experiment Station. V. Wetlands Research Program (U.S.) VI. Title. VII. Series: Wetlands Research Program technical report ; WRP-SM-17. VIII. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; WRP-SM-17.

TA7 W34 no.WRP-SM-17

Corps of Engineers Research Report Summary, December 1995

Avian Responses to Wetland Management

Avian Responses to Chemically and Physically Manipulated Cattail Stands in a Northern Prairie Marsh (TR WRP-SM-17)

ISSUE:

The value of cattail (*Typha* spp.)-dominated wetlands to waterfowl and other avian species is diminished following cattail invasion. Waterfowl and other bird species prefer wetlands with an interspersion of emergent cover and open water approximating a 50:50 ratio. Good interspersion increases dabbling duck use by providing visual isolation of conspecific pairs and may provide a cue to quality feeding habitat.

RESEARCH:

To create preferred conditions, *Typha*-dominated cattail stands were sprayed with glyphosate, cattail was winter-crushed with a Bombardier all-terrain vehicle, and cattail was both sprayed and winter-crushed. Two control treatments were used: (a) cattail impacted naturally by muskrats (*Ondatra zibethicus*) and (b) unmanipulated cattail. Responses of breeding waterfowl, passerine, and nonanatid waterbirds to the habitat treatments were identified.

SUMMARY:

Prior to cattail manipulation, most waterfowl use (59 percent) was associated with natural openings (≥2-m diam) in cattail. After manipulation, ≥88 percent of waterfowl observations in the crushed and spray/crushed treatments were in the crushed areas, and 47 percent of observations in the control were in openings created by muskrats. Avian species richness was significantly higher in crushed and spray/crushed treatments, primarily because of increased waterfowl diversity. Stem density of emergents prior to cattail manipulation averaged 48.2 stems/square meter in the muskrat-impacted control and 61.8 stems/square meter in the pretreatments and control. When spring water level is sufficient, winter crushing of dense cattail can significantly increase waterfowl pair use and control cattail while having little effect on most passerines and other non-Anatidae. Crushing should be used in combination with or as an alternative to spraying.

AVAILABILITY OF REPORT:

The report is available on Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199; telephone (601) 634-2355.

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About the Authors:

Mr. Mark J. Humpert was a Master of Science candidate at South Dakota State University and is now employed as a biologist with the Nebraska Game and Parks Commission. Dr. Daniel E. Hubbard is an Associate Professor in the Department of Wildlife and Fisheries Sciences, South Dakota State University. Dr. Kent C. Jensen is a wildlife ecologist at the WES Environmental Laboratory. Point of contact is Dr. Jensen at (601) 634-3047.

Contents

List of Figures

Preface

The work described in this report was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the critical processes Task Area of the Wetlands Research Program (WRP). The work was performed under Work Unit 32766, "Stewardship and Management Demonstration Studies," for which Mr. Chester O. Martin, U.S. Army Engineer Waterways Experiment Station (WES), was Technical Manager. Ms. Denise White (CECW-OW) was the WRP Technical Monitor for this work.

Mr. Dave Mathis (CERD-C) was the WRP Coordinator at the Directorate of Research and Development, HQUSACE; Dr. William L. Klesch (CECW-PO) served as the WRP Technical Monitors' Representative; Dr. Russell F. Theriot, WES, was the Wetlands Program Manager. Mr. Martin was the Task Area Manager.

This report was prepared by Mr. Mark J. Humpert and Dr. Daniel E. Hubbard, Department of Wildlife and Fisheries Sciences, South Dakota State University, and Dr. Kent C. Jensen, Stewardship Branch (SB), Natural Resources Division (NRD), Environmental Laboratory (EL), WES, under the general supervision of Mr. Hollis H. Allen, Acting Chief, SB, and Dr. Robert M. Engler, Chief, NRD. Dr. Edwin A. Theriot was the Assistant Director, EL, and Dr. John W. Keely was Director, EL.

Numerous individuals contributed to this study. Field assistance was provided by personnel from the U.S. Army Engineer White Rock Dam Field Office, U.S. Army Engineer District, St. Paul, and Mr. Tim Bertschi, St. Paul District, Western Area Reservoirs Office. Dr. Richard A. Fischer, Mr. Darrell Evans, and Mr. Martin, WES, offered thoughtful reviews of the manuscript. Dr. John Jenks, South Dakota State University, provided advice and assistance with statistical analyses.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

This report should be cited as follows:

Humpert, M. J., Hubbard, D. E., and Jensen, K. C. (1995). "Avian responses to chemically and physically manipulated cattail stands in a northern prairie marsh," Technical Report WRP-SM-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
miles (U.S. statute)	1.609347	kilometers

1 Introduction

Prior to the 1930s, common cattail (*Typha latifolia* L.) was the only member of this genus to inhabit the northern prairies and was uncommon in most shallow wetlands (Metcalf 1931). During the late 1930s and early 1940s, narrowleaf cattail (*T. angustifolia* L.) extended its range westward into the Dakotas and Manitoba (Smith 1967). Concomitant with the invasion of narrowleaf cattail was the establishment of a hybrid between narrowleaf and common cattail, *T.* X *glauca* (Godron).

Because both narrowleaf cattail and its hybrid are better adapted to fluctuating water regimes than common cattail (McDonald 1955), these species invaded shallow prairie wetlands. During the next 50 years, both spread rapidly throughout much of the Prairie Pothole Region (PPR) (Smith 1967), often forming dense monotypic stands in semipermanent wetlands (Stewart and Kantrud 1971).

The value of cattail-dominated wetlands to waterfowl and other avian species is diminished following invasion (Beule 1979; Kantrud 1986). Waterfowl and other bird species prefer wetlands with an interspersion of emergent cover and open water approximating a 50:50 ratio (Weller and Spatcher 1965; Weller and Fredrickson 1974; Murkin, Kaminski, and Titman 1982). Good interspersion increases dabbling duck use by providing visual isolation of conspecific pairs and may provide a cue to quality feeding habitat (Kaminski and Prince 1984).

Numerous techniques have been attempted to improve cattail-dominated wetlands for waterfowl by increasing interspersion (see reviews by Beule 1979; Kantrud 1986). These have included flooding (McDonald 1955; Millar 1973; Weller 1975), burning (Furniss 1938; Evans and Black 1956; Ward 1968; Smith 1969; Beule 1979; Gorenzel, Ryder, and Braun 1981), blasting (Mathisen, Byelich, and Radtke 1964; Mathiak 1965; Hopper 1972; Martin and Marcy 1989), grazing (Bue, Blankenship, and Marshall 1952; Munro 1963; Schultz et al. 1994), mechanical manipulation (Nelson and Dietz 1966; Weller 1975; Beule 1979) and spraying (Keith 1961; Weller 1975; Beule 1979; Solberg 1989).

Flooding is often the most effective technique for controlling cattail but requires water-level control capability (Weller 1975), which is not available for most PPR wetlands (Kantrud 1986). Winter burning of dense emergents can increase waterfowl pair use the following spring by removing residual cover (Schlictemeier 1967), but does not control cattail unless either the fire penetrates

the substrate and damages the rhizomes, or the burned stems are subsequently covered by water (Beule 1979).

Schultz et al. (1994) found that livestock grazing of dense stands of cattail during the growing season increased waterfowl pair use tenfold. When grazing was eliminated from a Costa Rican marsh, *T. domingensis* invaded and duck use decreased (McCoy, In Preparation). Bossenmaier (1964) recommended using cattle to crush solid stands of cattail and other emergents along the edges of marshes.

Cattail can be controlled by mechanical cutting during the growing season if old and newly cut stems are covered by at least 8 cm of water following treatment (Beule 1979). Likewise, cutting of standing dead stems during the winter or late spring can effectively control cattail if the cut stems are subsequently covered by water (Weller 1975). Scraping and discing cattail can improve waterfowl habitat but must be followed by flooding to achieve lasting results (Beule 1979; Sale and Wetzel 1983).

Mechanical crushing can open up dense stands of cattail and make them available to many wetland-associated birds (Beule 1979). Crushed areas will remain open for up to 4 years if the stems are covered by at least 15 cm of water. Cattail control may be maximized if crushing is performed when total nonstructural carbohydrates are at their lowest level (Linde, Janisch, and Smith 1976).

Herbicides have been used successfully to control emergent vegetation (Martin, Erickson, and Steenis 1957). Glyphosate is effective in controlling cattail in the PPR (Solberg 1989; Linz et al. 1991) and is superior to 2,4-D and Dalapon. Glyphosate causes little or no permanent damage to wetlands (Solberg 1989; Henry 1992) and is inactivated by soil particles (Stahlman and Phillips 1979), leading to rapid breakdown in the environment. Solberg (1989) found that glyphosate aerially applied to cattail-choked semipermanent wetlands increased waterfowl pair use and effectively controlled cattail. Openings created by spraying persisted for ≥4 years when water depth was sufficient. Glyphosate is currently being used by many wetland managers in the PPR (Solberg and Higgins 1993).

Native herbivores such as muskrats (*Ondatra zibethicus*) can be effective in controlling cattail (Errington 1963). Muskrats are the most efficient primary consumer of cattail in the northern Great Plains and prefer cattail over other emergents for both food and lodge building (Errington 1963). They can open up dense stands of cattail and improve an area for waterfowl by creating hemi-marsh conditions (approximate 1:1 ratio of open water to emergent vegetation) (Weller and Spatcher 1965; Weller and Fredrickson 1974). White-tailed deer (*Odocoileus virginianus*) will browse on young sprouts of cattail but have a less important effect than muskrats (Beule 1979).

Management of muskrat populations is the most efficient and inexpensive technique to manage northern prairie marshes for waterfowl (Weller 1975). However, in the Great Plains, muskrat populations often fluctuate widely

because of drought, disease, and eat-outs (Errington 1963). Once eliminated from an isolated wetland, recolonization may take many years. An attempt to increase the rate of recolonization through transplanting in the PPR was mostly unsuccessful (Kjellsen 1988).

The purpose of this research project was to assess the effectiveness of mechanical crushing as a technique to improve waterfowl breeding pair and brood habitat and if crushing impacted other avian species or muskrats. Results from this study will be used to formulate management recommendations for Mud Lake.

2 Study Area

Mud Lake is a 1,750-ha water control area comprised of a mosaic of seasonally flooded and semipermanently flooded wetlands (classified according to Cowardin et al. 1979) interspersed with large tracts of upland areas. It is located on the Minnesota/South Dakota border approximately 10 km east of Rosholt, SD (Figure 1).

White Rock Pool, situated on the south end of Mud Lake, is the primary water storage area and has a maximum water depth of approximately 130 cm at normal pool levels (Figure 2). The area is bounded by two dams: Reservation Dam forms the southern boundary and separates Lake Traverse; White Rock Dam provides the northern boundary and supplies the headwaters to the Bois de Sioux River.

The area is managed by the U. S. Army Corps of Engineers (CE) as part of the Lake Traverse Flood Control Project. The managed growing season water level following spring runoff has been set at 296.3 m (972 ft) msl per agreement with local landowners and resource agency personnel.[1] Maximum flood storage capacity for Mud Lake is 299 m (981 ft) msl. It is a meandered lake and upland; meadow areas are used for hay production and livestock grazing during the growing season. The area is used extensively in the fall and winter for hunting and trapping.

Dams were constructed in the early 1940s for flood water storage. Prior to dam construction, the area consisted of numerous northward flowing channels. Most of these channels are now impeded by siltation and choked by dense emergents, particularly cattail. The present water regime prevents flowage through these natural channels during most of the year.

In 1983, the CE contracted with the U.S. Fish and Wildlife Service (USFWS) to initiate a vegetative study of Mud Lake. Kantrud found the quality and quantity of waterfowl habitat deficient for breeding pairs and broods principally because of a loss of hemimarsh to robust unbroken stands of emergents.[2] In

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[1] Personal Communication, 1992, Dave Salberg, Park Ranger, U.S. Army Engineer District, St. Paul, St. Paul, MN.

[2] Unpublished Material, 1983, H. A. Kantrud, "Mud Lake Wildlife Management Plan," U.S. Army Corps of Engineers, St. Paul, MN.

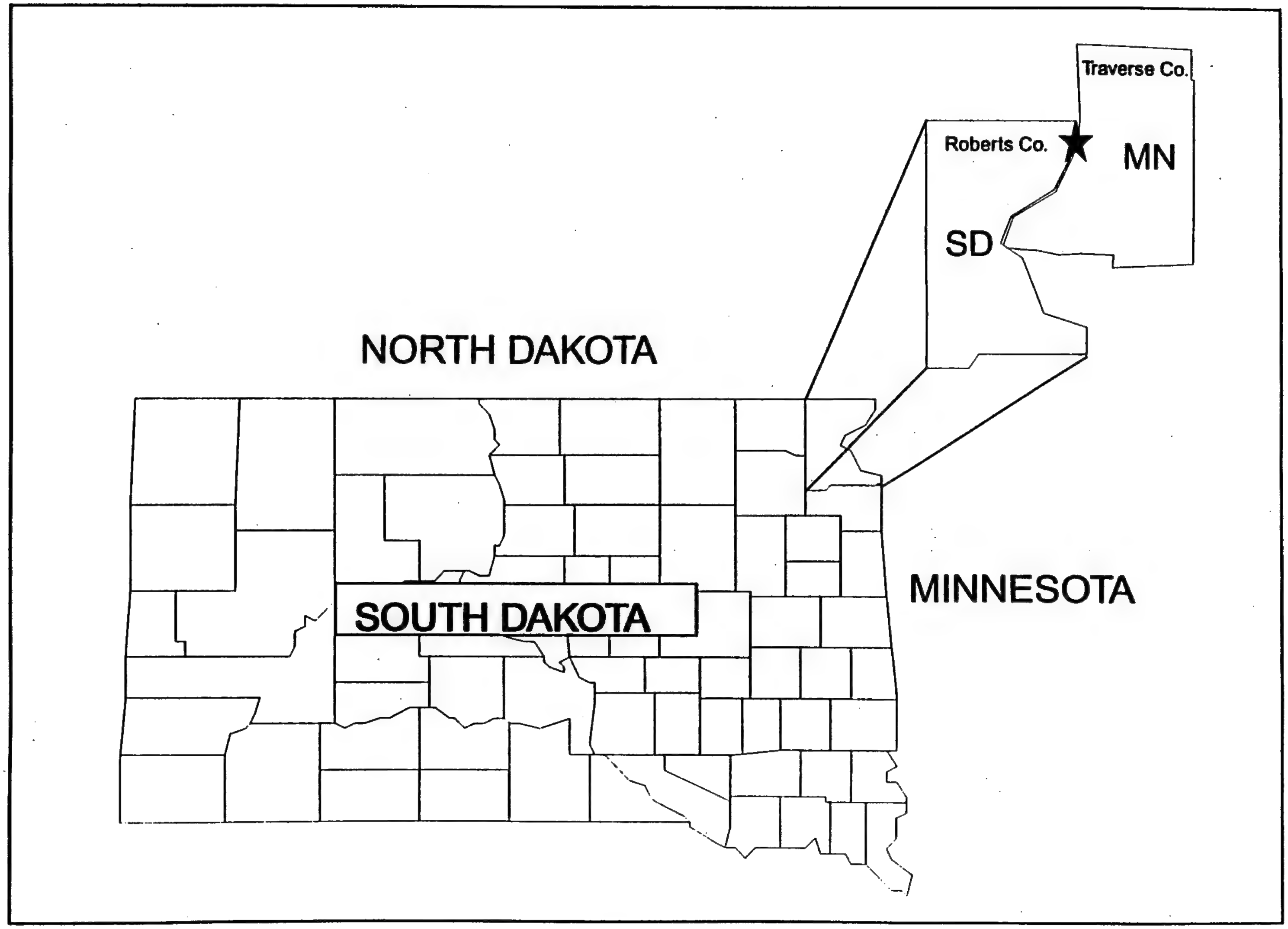

Figure 1. South Dakota map showing approximate location of Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota

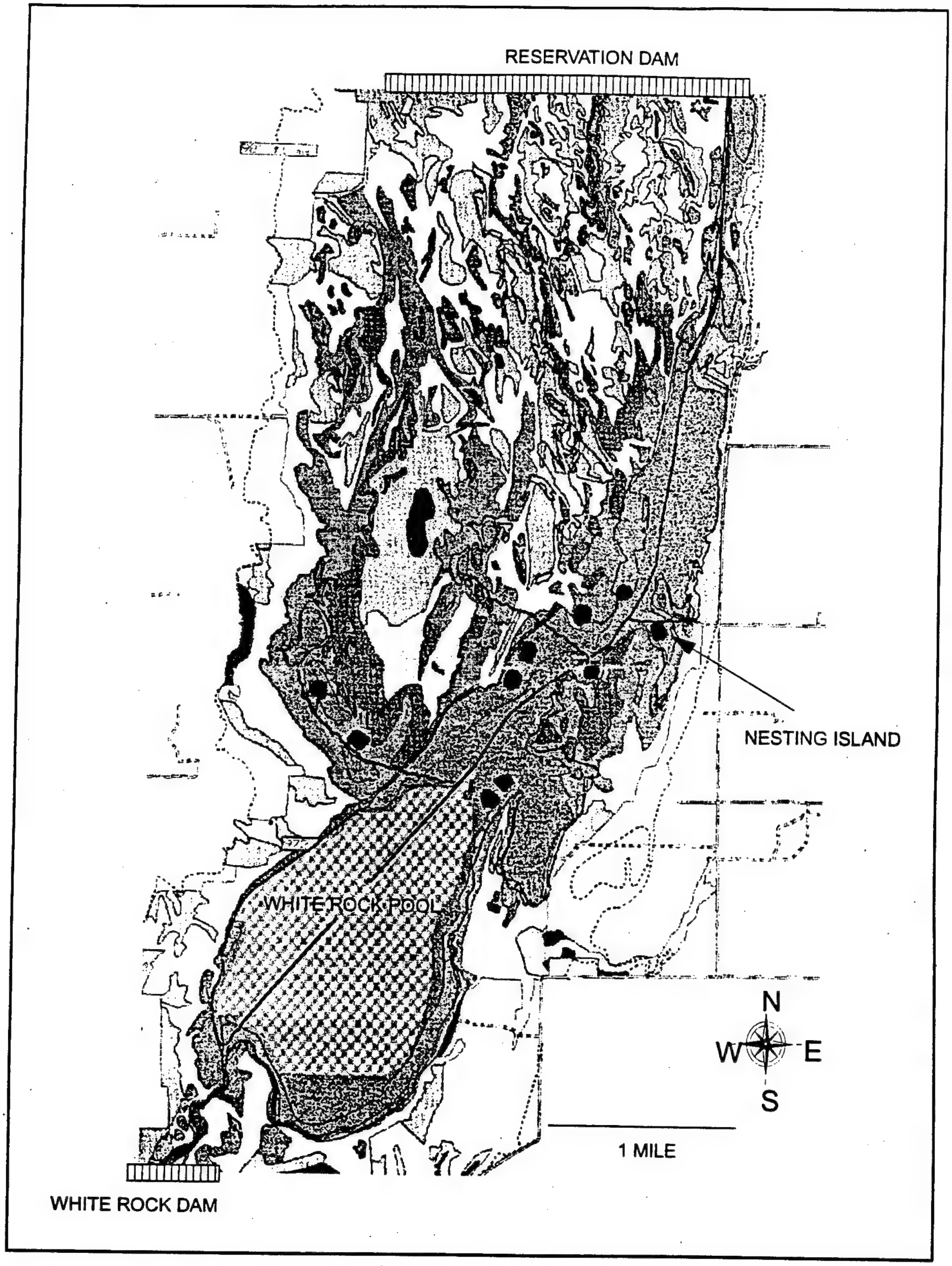

Figure 2. Map of Mud Lake showing location of major features

addition, he observed a near total absence of submergent vegetation such as sago pondweed (*Potamogeton pectinatus*) and attributed its decline to shading by emergents and suspended algae and turbidity from rough fish.

Kantrud recommended changing the present stabilized water regime and replacing it with one that fluctuates annually, similar to the natural wetland cycle typical of prairie wetlands.[1] He suggested that a 5-year cycle be used beginning with a drawdown and followed by a gradual raising of the water level to 296.9 m (974 ft) msl. In addition, he recommended that dense stands of cattail be burned and/or grazed and then flooded to increase interspersion and improve the overall quality of wetlands for waterfowl. The drawdown and subsequent reflooding would be facilitated by dredging the channel that runs through Mud Lake.

Sociopolitical constraints delayed implementation of the recommendations made by Kantrud. Since the city of Wahpeton, ND, receives a portion of its drinking water supply from the Bois de Sioux river, concern was raised that increased flows from Mud Lake during the summer would foul drinking water supplies. In addition, some private landowners were concerned that higher water levels would disrupt farming practices and that fire was too risky as a management alternative because of exceedingly high fuel loads. Some sportsmen felt that changes in the current water regime would negatively impact hunting.

However, in 1988 after consultation with private landowners, the Mud Lake Management Group initiated a restoration project with the participation of the CE, Ducks Unlimited (DU), South Dakota Department of Game Fish and Parks (SDGF&P), Minnesota Department of Natural Resources, and the USFWS. Mud Lake was dewatered, several miles of level ditches were dredged, and ten 0.40-ha nesting islands were built to improve the area for nesting and migrating waterfowl. It was agreed that the post-runoff water level (conservation pool) would be set at 296.3 m (972 ft) msl. Since 1989, annual nest searches and brood counts have been conducted by DU and SDGF&P personnel to assess waterfowl use at Mud Lake. To improve nest success on nesting islands, SDGF&P personnel attempted to remove predators from nesting islands in 1992.[2]

Muskrats were significantly reduced following the drawdown in 1988, but their numbers increased during the early 1990s.[3] Stabilized winter water levels, an abundance of food, reduced trapping pressure, several mild winters, and improvements from dredging activities probably contributed to the recent increase in muskrats.

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[1] Unpublished Material, 1983, H. A. Kantrud, "Mud Lake Wildlife Management Plan," U.S. Army Corps of Engineers, St. Paul, MN.

[2] Personal Communication, 1993, S. Vaa, State Waterfowl Biologist, South Dakota Department of Game Fish and Parks, Brookings, SD.

[3] Personal Communication, 1993, D. Salberg, Park Ranger, U.S. Army Engineer District, St. Paul, White Rock Dam, Wheaton, MN.

3 Methods and Materials

Avian Surveys

During May of 1992, shallow (<50 cm) semipermanent wetlands with dense stands of cattail were selected for avian-use surveys. Thirty-nine 250- by 40-m (1-ha) belt transects were marked with steel fence posts and colored flagging. A footpath 50 to 100 cm wide down the center of each belt was made by trampling cattail, and 50-m intervals were marked with colored flagging. In 1993, four additional belts were set up in a similar manner in two semipermanent wetlands containing dense stands of river bulrush (*Scirpus fluviatilis*) and cattail.

In 1992, four avian surveys were conducted between 0530 and 0830 hr CDT from June 1-July 10, prior to vegetation manipulation (pretreatment), to compile baseline data and to test for pretreatment homogeneity. Survey periods coincided with times of peak breeding activity for several common passerines (Whitney et al. 1978) and ducks (Sauder and Linder 1969). In 1993, seven avian surveys were conducted between May 8 and July 29 along the 39 original belts. Seven additional surveys of aquatic birds only were conducted from May 27-July 22 along the four supplemental belts laid out in 1993.

Avian species were surveyed using procedures similar to those used by Hubbard (1982) and following guidelines recommended by Verner (1985). All avian species detected visually or aurally within the belt were recorded on standardized data sheets. Waterfowl breeding pairs were enumerated following procedures described by Hammond (1969), and social groups were interpreted as breeding pairs according to Dzubin (1969). Birds flying into or over the belt were not counted, and birds flushing from within the belt were noted to prevent duplicate counts. A constant pace of about 1 km/hour was maintained to help ensure consistency among surveys.

Surveys were conducted when temperatures were ≥4 °C and winds <20 mph.[1] Surveys were not conducted during periods of moderate to heavy rainfall or dense fog. Water depth was recorded at 50-m intervals along the transect line during each survey. Evidence of muskrat sign (lodge, feed beds, cuttings, and droppings) were recorded during avian surveys so that muskrat use could be determined.

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[1] A table of factors for converting non-SI units of measurement to SI units is presented on page xii.

Spatial characteristics of sites used by waterfowl were recorded during both years. In 1992, microsite structure of waterfowl observations was noted and placed into one of four categories: emergents (no or <2-m-diam opening), natural opening (opening ≥ 2-m-diam), tractor track, and deer trail. The tractor tracks were made incidental to this study with a farm tractor in the winter of 1991 and 1992. In 1993, three categories were used in addition to the other four: muskrat (opening in emergents near a muskrat house), all-terrain vehicle (ATV) circle (ATV-crushed circular area; see below for description), and ATV track (area crushed by ATV outside of circular area).

During January of 1993 and 1994, muskrat houses were counted along avian survey belts. An ice auger was used to drill a hole in the ice 1 to 2 m from the edge of the muskrat house. Ice thickness and water depth were recorded for each house.

Vegetation Survey

After completion of avian surveys in 1992, vegetative characteristics were measured in 20 stratified random quadrats (4 quadrats per 50 m) within each belt. Quadrats measured 1.0 by 0.5 m (0.5 m^2) in size and were a collapsible rectangular polyvinyl chloride (PVC) frame. Quadrats were placed from 1 to 20 m from the center of the transect belt. Vegetative measurements included the following: water depth, number of live emergent stems (leaves and fruiting stalks), average height of live stems, number of dead stems greater than 1 m, canopy coverage of dead stems, canopy coverage of submergents, and an estimate of interspersion.

Canopy coverage estimates followed Daubenmire (1959), but were modified to include seven coverage classes: 0 (not present), 1 (>0- to 5-percent cover), 2 (6- to 25-percent cover), 3 (26- to 50-percent cover), 4 (51- to 75-percent cover), 5 (76- to 95-percent cover), and 6 (96- to 100-percent cover). Each quadrat was subdivided into four equal rectangular partitions using elastic bands so that four canopy coverage estimates could be taken at each site. This allowed estimation of canopy coverage with a minimum of ocular movement and thus provided a more accurate approximation of percent coverage. The mean of the four estimates was taken as the overall estimate of canopy coverage. Interspersion was measured by ocularly estimating the amount of open water in a 10-m-diam circle centered on the quadrat.

Vegetative measurements were taken within spring-crush transect belts during the winter following manipulation. Two random quadrats were placed inside and two quadrats outside (one to the north and one to the south of the crushed circle) each crushed circle. The number of dead standing stems and canopy coverage were measured at each of the 48 quadrats.

Cattail Destruction

Following vegetation surveys, 14 belts were selected based on water depth and location and marked with 1-m^2 sheets of black polyethylene plastic. Glyphosate (Rodeo) was aerially applied at a rate of 0.86 ℓ/hectare in three 9.1-m-wide swaths centered over each of the 14 belts. Spreader 90 was used as a surfactant (0.008 ℓ/hectare) and Chemtrol (0.095 ℓ/hectare) as a drift retardant to reduce the risk to nearby agricultural fields and controls. Spraying was originally planned to be conducted the last week of August (Solberg 1989), but was delayed 3 weeks because of unfavorable winds and scheduling difficulties with the pilot. Spraying was completed more than 2 weeks prior to the first subfreezing temperatures of the season.

During mid-January, portions of six sprayed and six unsprayed belts were crushed over the ice with a Muskeg Carrier Bombardier ATV. The Bombardier was equipped with two 358- by 71-cm caterpillar treads. Eight circles (four on each side of belt center) were crushed and averaged approximately 0.018 ha/circle (Figure 3). The Bombardier was driven in a circular and back-and-forth direction until all standing vegetation was knocked down.

Fifteen to twenty minutes were needed to crush each circle. Forty to one hundred centimeters of snow on top of the ice slowed crushing and reduced compaction to 10 to 15 cm above the ice. The diameter of the crushed circles averaged slightly larger than originally planned (0.015 ha/circle) because snow limited the turning radius on the Bombardier.

The study design included 39 belt transect segments with the following treatments and controls: sprayed with glyphosate (8 belts), crushed (6 belts), sprayed and crushed (6 belts), muskrat-impacted (6 belts), and control (13 belts). Muskrat-impacted areas consisted of sites where recent muskrat activity had reduced stem density and increased interspersion.

On May 28, the Bombardier was used to crush portions of two of four supplemental 1-ha belts to test the effects of spring crushing on waterbird use and cattail control. Six circles, averaging approximately 0.015 ha each, were made employing similar methods used for winter crushing. The water depth at the time of crushing ranged from 20 to 60 cm, and approximately 10 to 15 min was required per circle.

Statistical Procedures

Five belt-transect segments used as controls and two used as muskrat-impacted controls were excluded from analysis because water depth averaged <10 cm during the four avian surveys in 1992. Therefore, a total of 32 belts were used for analysis of pretreatment and winter crushing data. Four belt transects were used for analysis of spring crushing data.

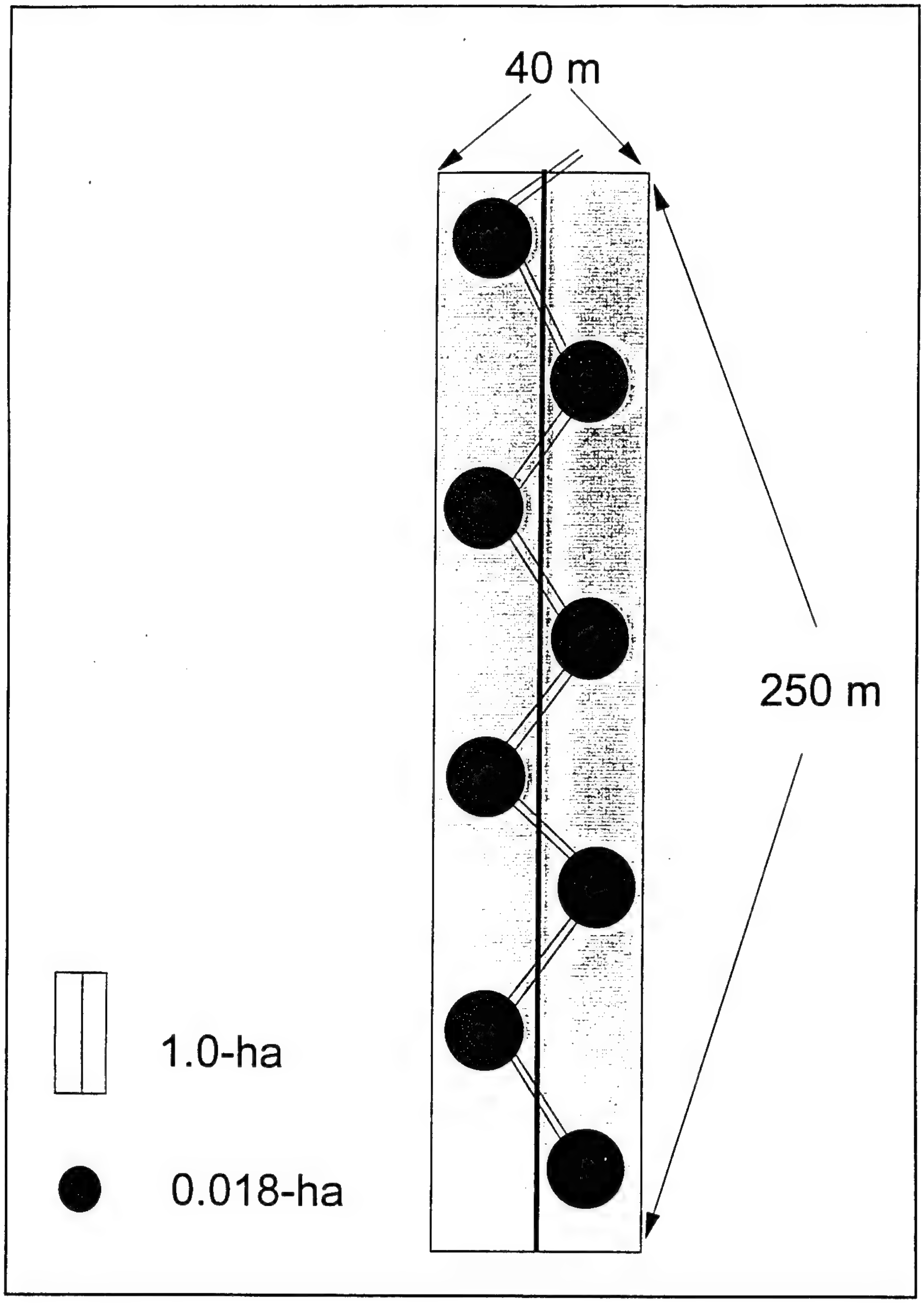

Figure 3. Position of crushed cattail areas (circles) and ATV tracks within a 1-ha avian survey-belt transect

Means were calculated for each avian species by survey period and plotted to determine peak breeding times. The survey period with the largest mean plus those survey periods just prior to and after the peak were used for statistical analysis. In cases where no obvious peak was present, three contiguous surveys corresponding to the peak breeding time of that species was used. Species with

few observations were grouped into family or other meaningful assemblages for analysis.

Data were rank transformed to stabilize variances and to otherwise meet the assumptions of analysis of variance (ANOVA) (Conover and Iman 1981). The general linear model procedure for unbalanced designs (SAS Institute, Inc. 1988) was used to perform an ANOVA on the ranks of three surveys to test for an overall difference in mean relative densities (MRD) between treatments. If a significant difference was detected, a least square means test was used to separate differences. An alpha level of $P \leq 0.05$ was considered significant. Spearman rank correlation coefficients were used as an exploratory statistical technique to determine if correlations existed among avian species.

Live stem density data were analyzed using the same procedures used to test for differences in avian species. Since spring-crushed vegetation data had a balanced design but were not normally distributed, the Wilcoxan signed-rank test was used for analysis. An alpha level of $P \leq 0.05$ was considered significant.

4 Results

Water Levels

The mean water depth of the 32 avian survey belts differed significantly between years (1 df, $P \leq 0.0001$) (Figure 4). The water depth in 1992 averaged 23.0 cm compared with 53.9 cm in 1993. The higher water depth in 1993 resulted from above-average spring runoff (Figure 5) and increased spring and summer precipitation (Figure 6).

Near record rainfall during the summer of 1993 caused water levels in White Rock Pool to rise to the highest recorded level for August and the second highest for July (Figure 7). The severest flooding occurred after the first week of July when White Rock and Reservation dams were closed to reduce downstream flooding. Because of this severe flooding, avian surveys conducted in 1993 after the first week of July were not used for analysis since most cattail in the survey belts was completely submersed.

Vegetation Survey

Eighteen species of emergent vegetation were observed during surveys within avian transect belts. Cattail was the most abundant species and accounted for 69 percent of live stems. River bulrush was the next most abundant and made up 22 percent of live stems followed by hardstem bulrush (*Scirpus acutus*) at 6 percent, and three-square (*Scirpus pungens*) at 2 percent (Figure 8). Live-stem density ranged from 63.8 stems/square meter (SE = 3.2) in the precrush treatment to 48.2 stems/square meter (SE = 5.4) in the muskrat-impacted control (Figure 9). Live-stem density in the muskrat-impacted control was significantly lower than the control and all pretreatments (4 df, $P \leq 0.05$). Canopy coverage of dead emergent stems was lowest in the muskrat-impacted control (4 percent) and was highest in the prespray treatment (49 percent) (Figure 10). Interspersion was highest in the muskrat-impacted control (14 percent) and lowest in the prespray treatment (1 percent) (Figure 11).

A vegetation survey was not conducted in 1993 because of flooding. From mid-July through August, vegetation within belt transects was completely submersed by floodwaters, and access to these areas was possible only by boat. However, in early July, just prior to the onset of severe flooding, most areas that were sprayed had few live aerial shoots compared with adjacent unsprayed areas,

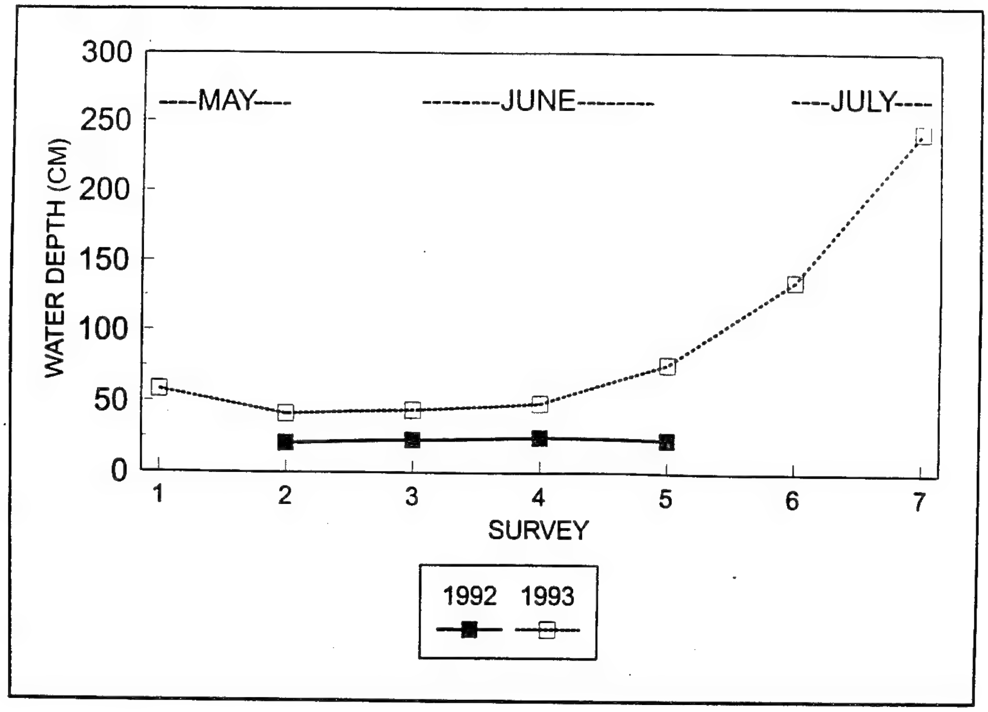

Figure 4. Mean water depth along avian survey-belt transects, 1992 and 1993, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (overall mean water depths differed significantly between years (1df, P < 0.001))

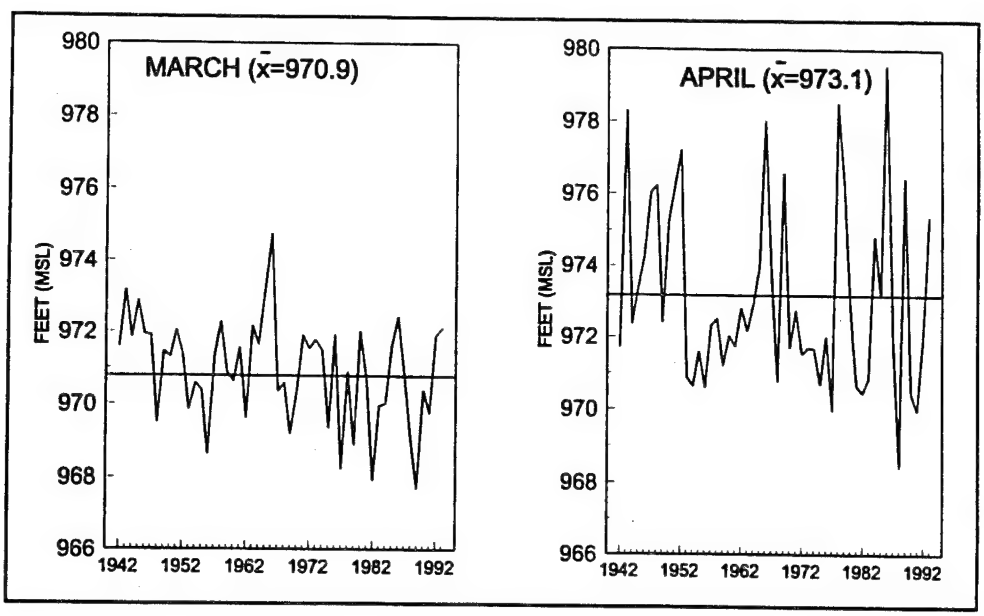

Figure 5. Mean monthly water levels, March and April (1942-1993), White Rock Pool, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota

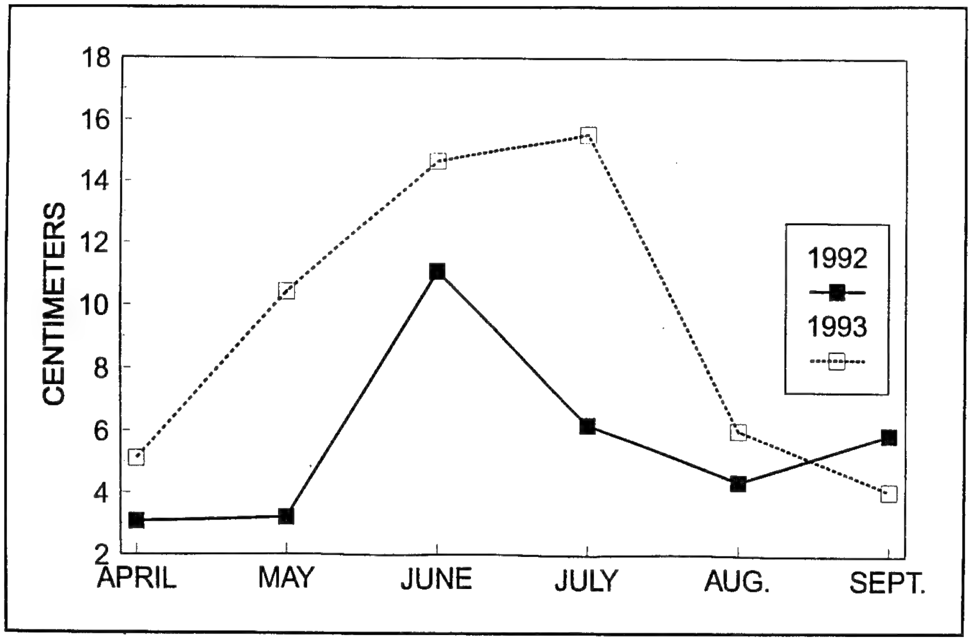

Figure 6. Mean monthly precipitation from April-September 1992 and 1993 recorded, White Rock Dam, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota

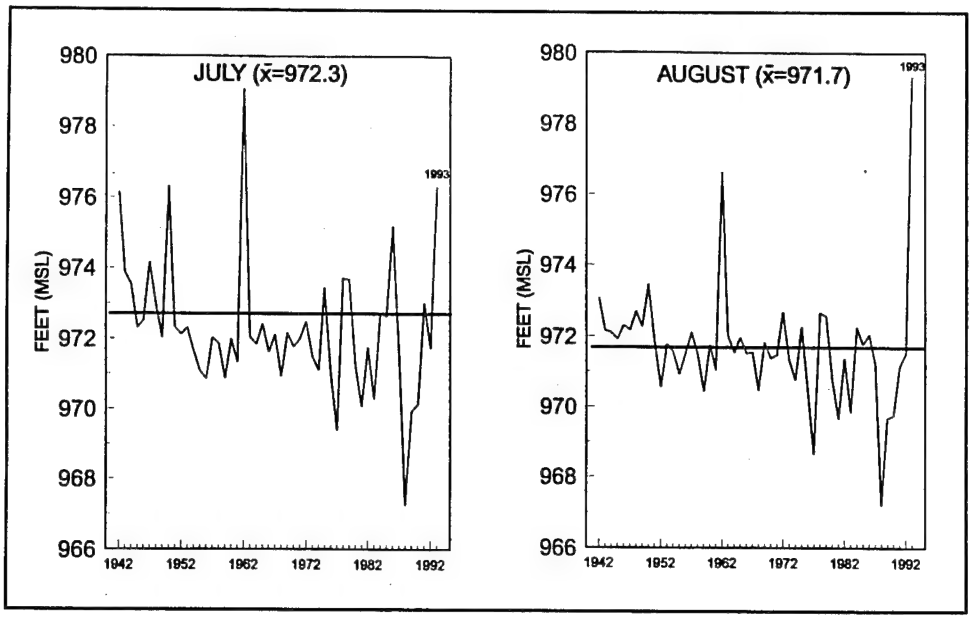

Figure 7. Mean water depth of White Rock Pool for July and August from 1942-1993, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (July 1993 water depth (976.3 ft MSL) was second highest on record and August 1993 water depth (979.33 ft MSL) was highest on record)

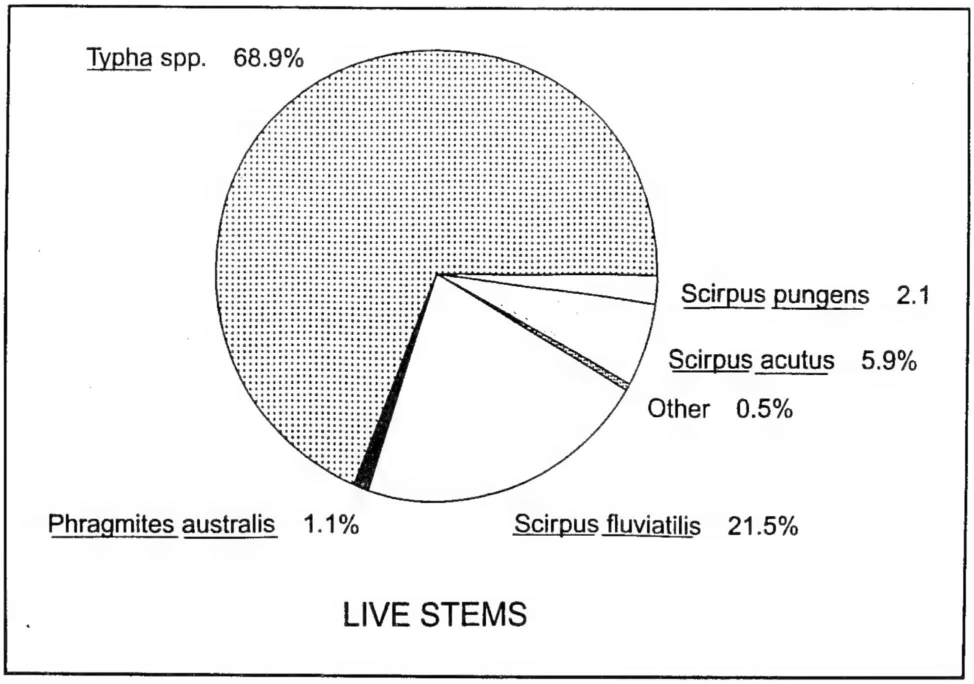

Figure 8. Percent composition of live emergent stems along avian-survey transects during summer of 1992, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota

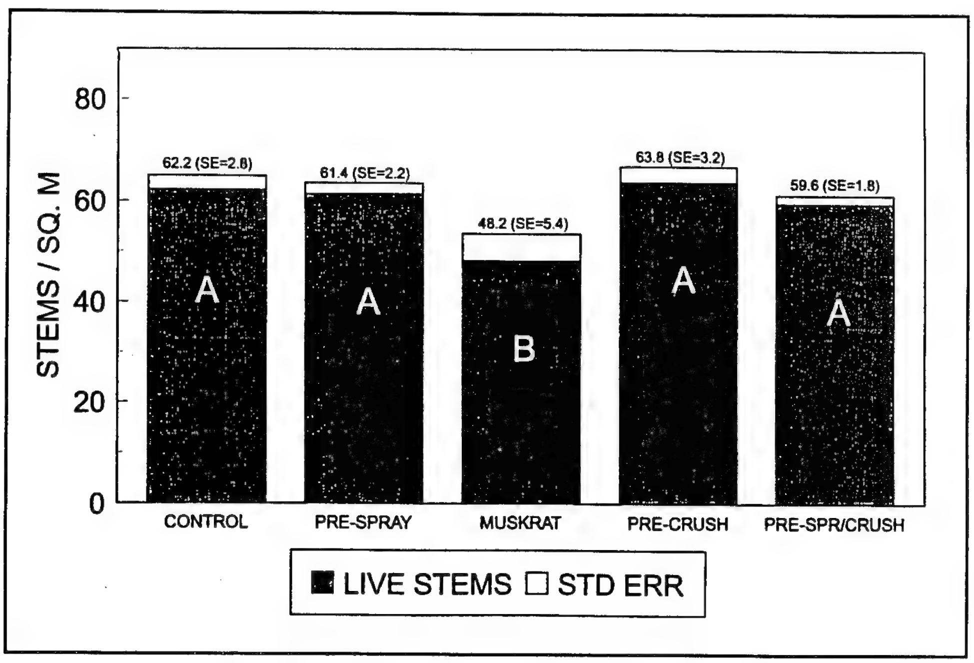

Figure 9. Mean stem density of emergents (*Typha, Scirpus, Phragmites*) within transect segments in 1992 prior to manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with different letters are statistically different ($P < 0.05$))

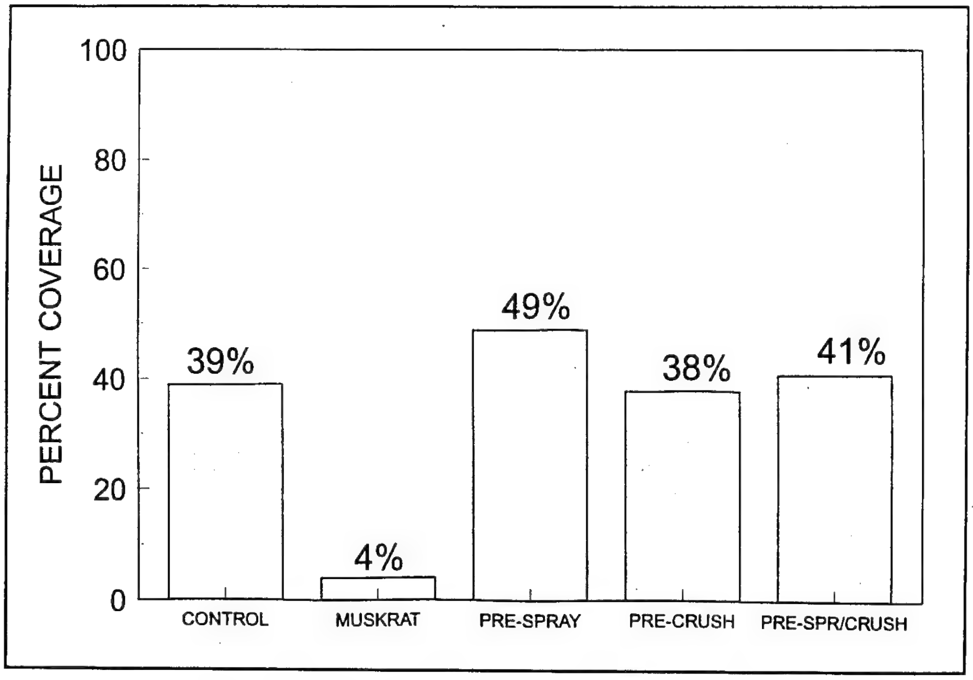

Figure 10. Canopy coverage of dead standing and fallen emergent stems in 1992 prior to cattail manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota

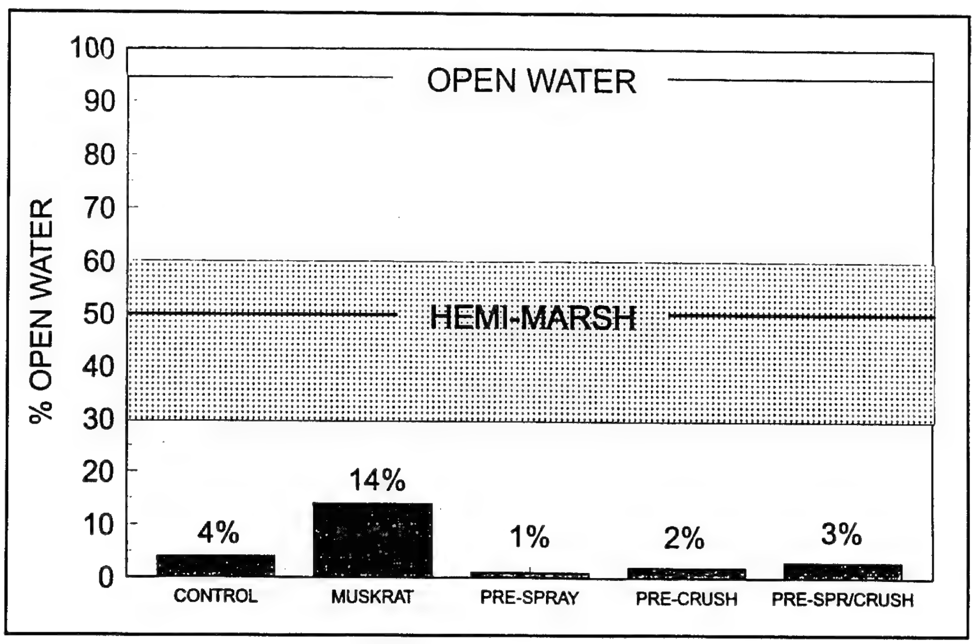

Figure 11. Mean interspersion index rating within transect segments in 1992 prior to cattail manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (rectangular box represents ideal cover-to-water interspersion (Weller 1975))

which had robust stands of emergents. Live shoots that were present in the sprayed transects were confined to the periphery of the sprayed areas. Emergents were also absent from most crushed areas. However, a small number (n = 3) of crushed circles did have a large number of live aerial shoots, although still considerably fewer shoots than in adjacent uncrushed areas. Vegetative measurements planned for the winter of 1993-94 were not possible because deep snow covered most residual emergent stems, making vegetative measurements impossible.

Avian Surveys

In 1992, 20 species were observed during avian surveys (scientific names for these birds are included in Appendix A). Mean species richness did not differ between pretreatment belts or controls (4 df, $P = 0.40$) (Figure 12). Marsh wrens had the highest overall mean relative density (MRD) (9.65/hectare; SE = 0.30) followed by yellow-headed blackbirds (1.40/hectare; SE = 0.23). There were no significant differences in MRD between pretreatment belts or controls for marsh wrens, yellow-headed blackbirds, or red-winged blackbirds (4 df, $P \geq 0.05$) (Figures 13-15).

At Mud Lake, common yellowthroats, song sparrows, swamp sparrows, brown-headed cowbirds, and sedge wrens inhabit the drier shoreward fringes of cattail stands. Since these species use similar habitats and their densities were too low for individual analysis, these species were pooled and termed the fringe species group (FSG) for analysis. Soras and Virginia rails were also observed at

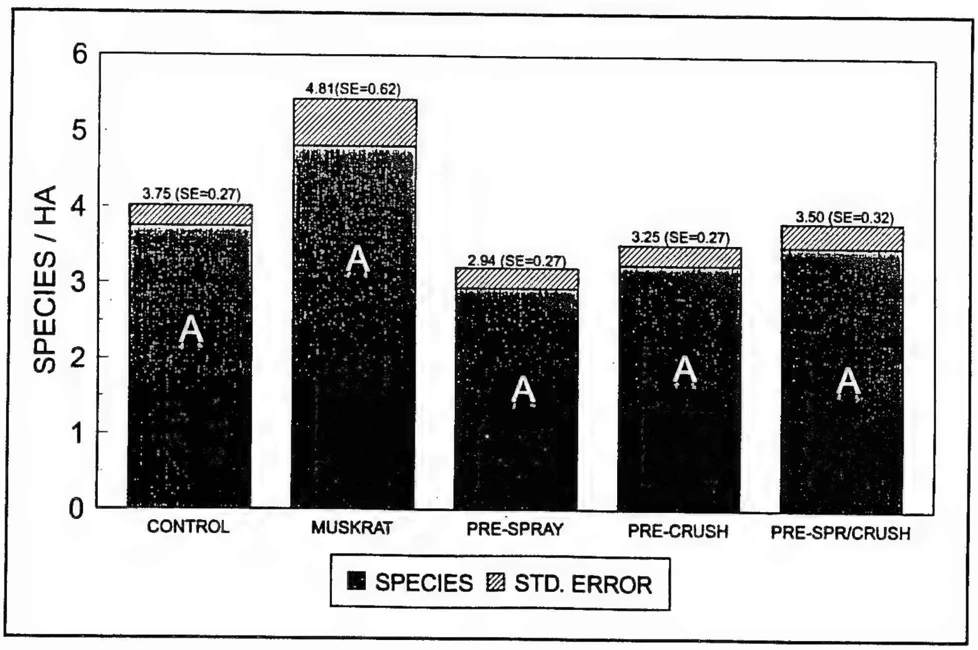

Figure 12. Mean number of species observed in 1992 prior to cattail manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different (P > 0.05))

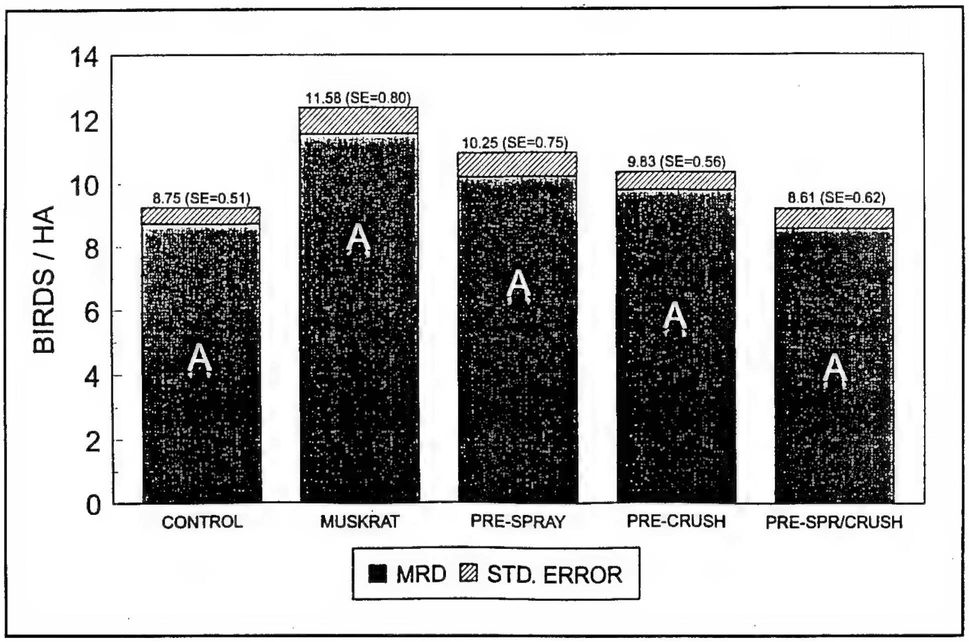

Figure 13. Mean relative density of marsh wrens in 1992 prior to cattail manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different (P > 0.05))

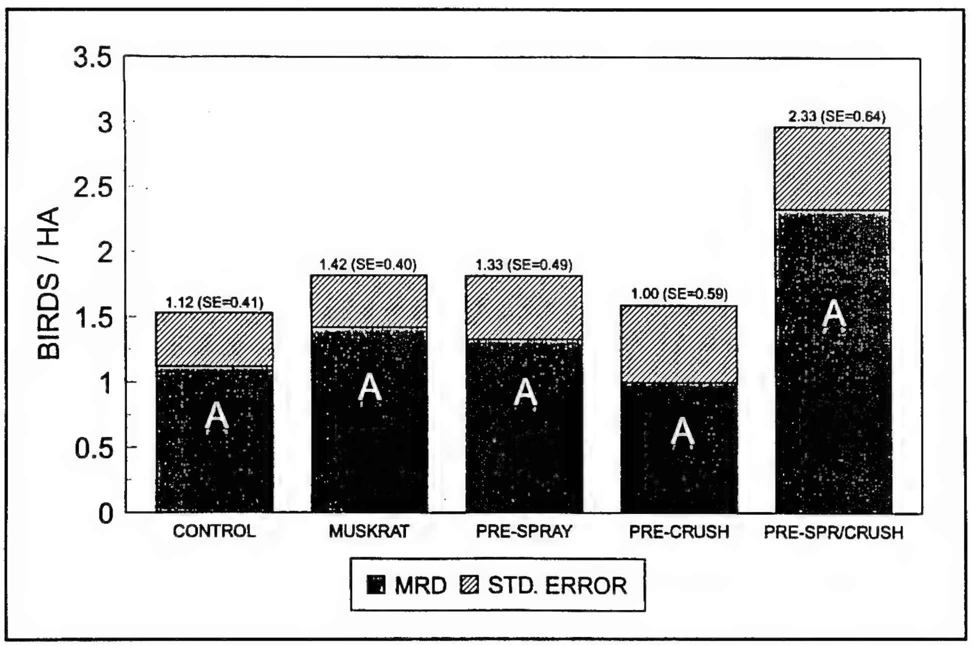

Figure 14. Mean relative density of yellow-headed blackbirds in 1992 prior to cattail manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different (P > 0.05))

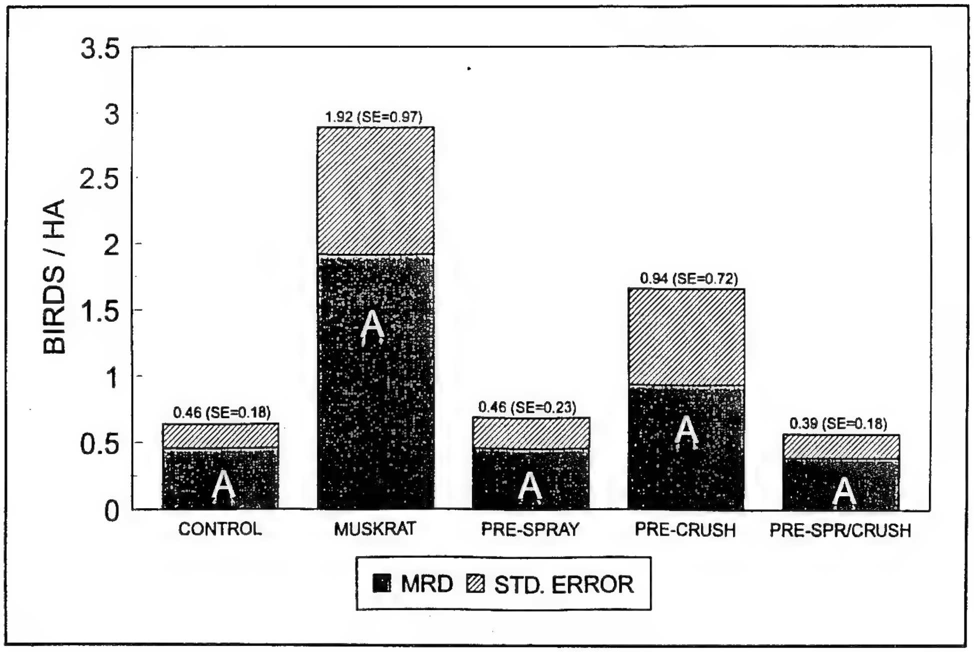

Figure 15. Mean relative density of red-winged blackbirds in 1992 prior to cattail manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different ($P > 0.05$))

low densities and were similarly pooled (aggregate rails) for analysis. There were no significant differences (4 df, $P \geq 0.05$) between pretreatment belts or controls for either the FSG or aggregate rails groups (Figures 16-17).

Blue-winged teal was the most abundant waterfowl species with an overall MRD of 0.42 pairs/hectare (SE = 0.28) followed by mallards with an overall MRD of 0.15 pairs/hectare (SE = 0.28). Since waterfowl densities were low, observations were pooled (aggregate ducks) for analysis. Mean relative densities of aggregate ducks were not significantly different between pretreatment belts or controls (4 df, $P \geq 0.05$) (Figure 18). A comprehensive list of MRDs for all species is included in Appendixes B and C.

In 1993, 31 species were observed during avian surveys (Appendix A). Mean species richness in the crushed treatment was significantly higher than the control or sprayed treatment (4 df, $P \leq 0.05$) (Figure 19). Marsh wrens and yellow-headed blackbirds were the most abundant species with overall MRDs of 7.57/hectare (SE = 0.31) and 7.53/hectare (SE = 0.64), respectively. There were no significant differences between treatments and controls for yellow-headed blackbirds, marsh wrens, FSG, aggregate rails, or coots (4 df, $P \geq 0.05$) (Figures 20-24).

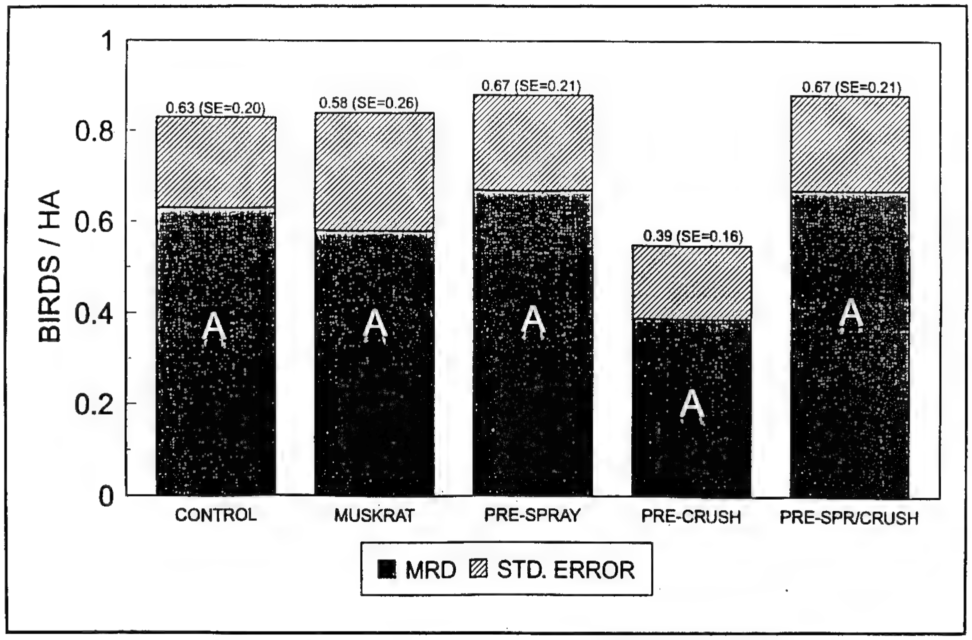

Figure 16. Mean relative density of aggregate common yellowthroats, song sparrows, swamp sparrows, brown-headed cowbirds, and sedge wrens in 1992 prior to cattail manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different (P > 0.05))

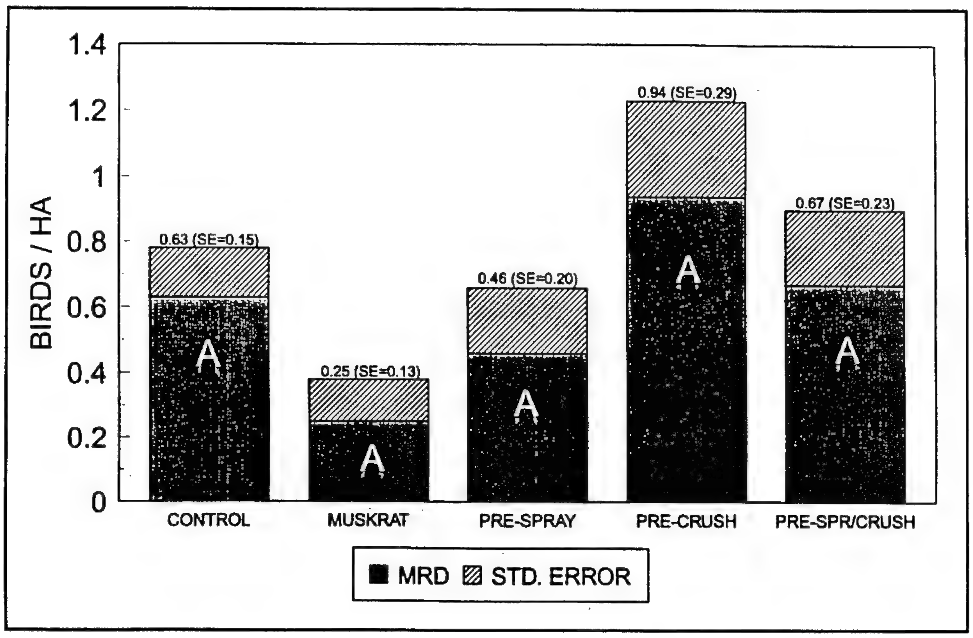

Figure 17. Mean relative density of aggregate soras and Virginia rails in 1992 using dense cattail (*Typha* spp.) prior to manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different (P > 0.05))

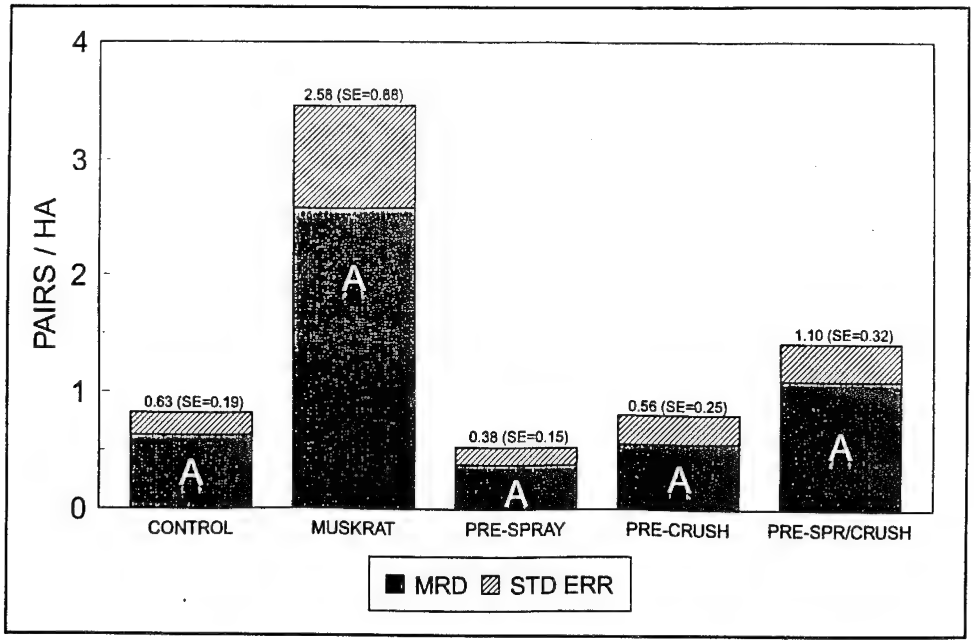

Figure 18. Mean relative density of aggregate blue-winged teal, mallards, gadwalls, redheads, wood ducks, northern shovelers, and green-winged teal in 1992 using dense cattail prior to manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different (P > 0.05))

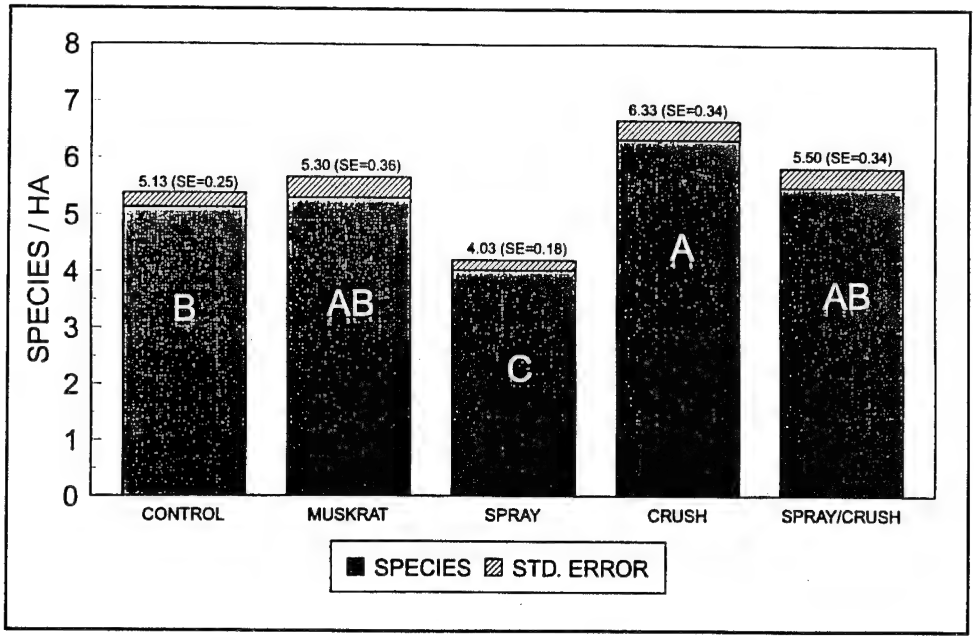

Figure 19. Mean number of species observed in 1993 prior to cattail manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different (P > 0.05))

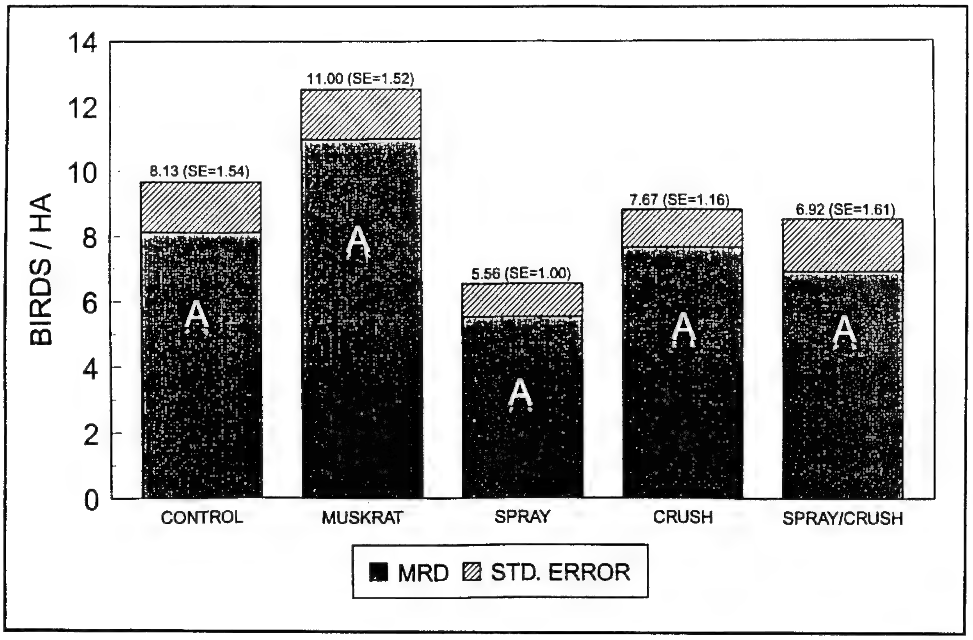

Figure 20. Mean relative density of yellow-headed blackbirds in 1993 using dense cattail after manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different (P > 0.05))

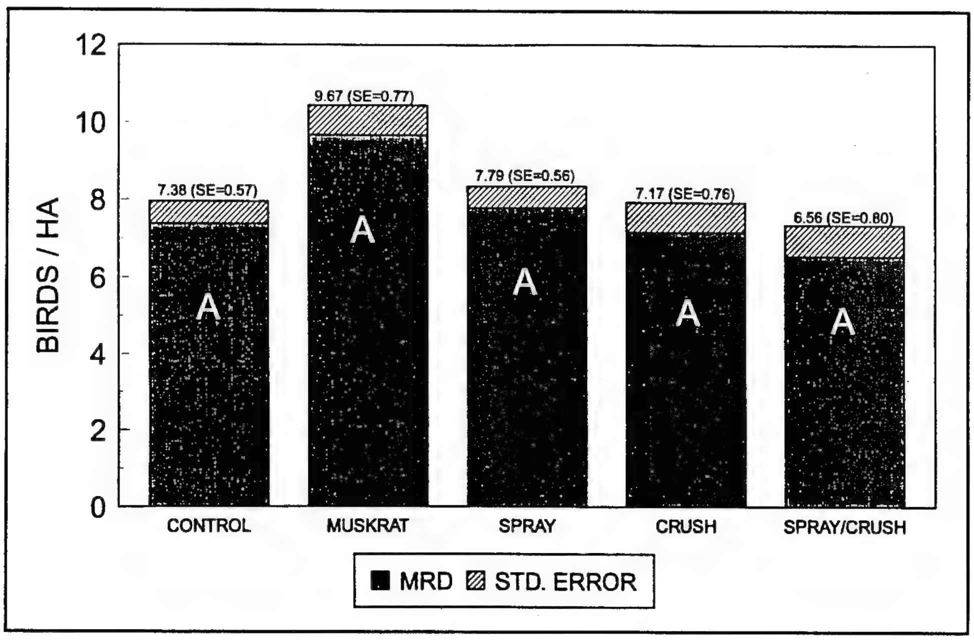

Figure 21. Mean relative density of marsh wrens in 1993 using dense cattail after manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different (P > 0.05))

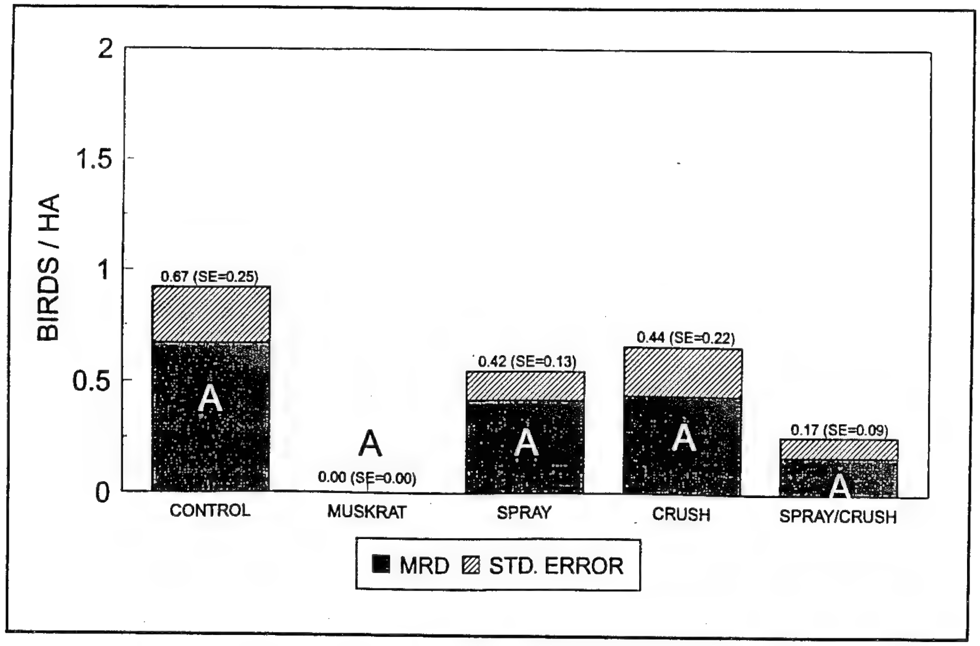

Figure 22. Mean relative density of aggregate common yellowthroats, song sparrows, swamp sparrows, and brown-headed cowbirds in 1993 after cattail manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different (P > 0.05))

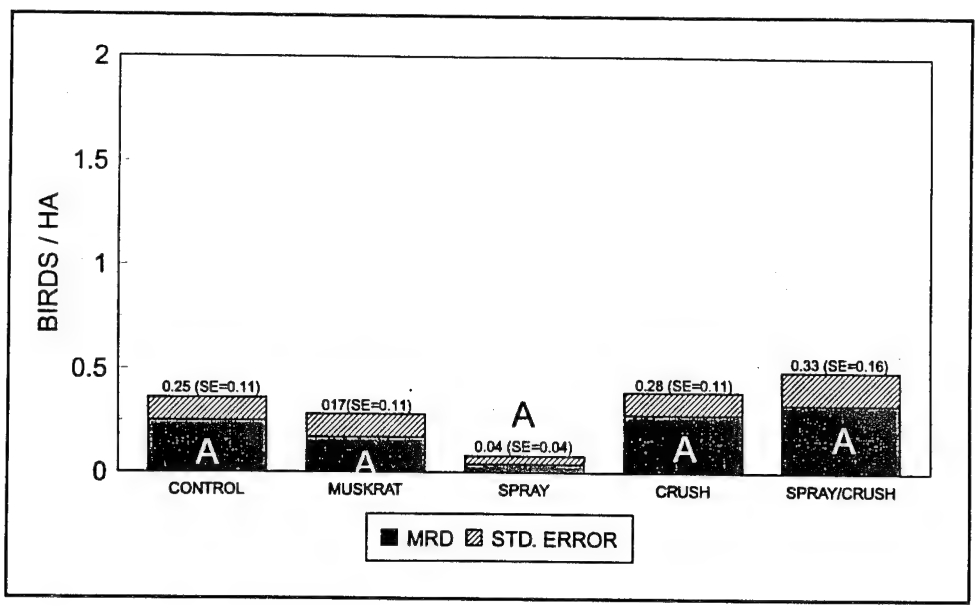

Figure 23. Mean relative density of aggregate soras and Virginia rails in 1993 using dense cattail after manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different (P > 0.05))

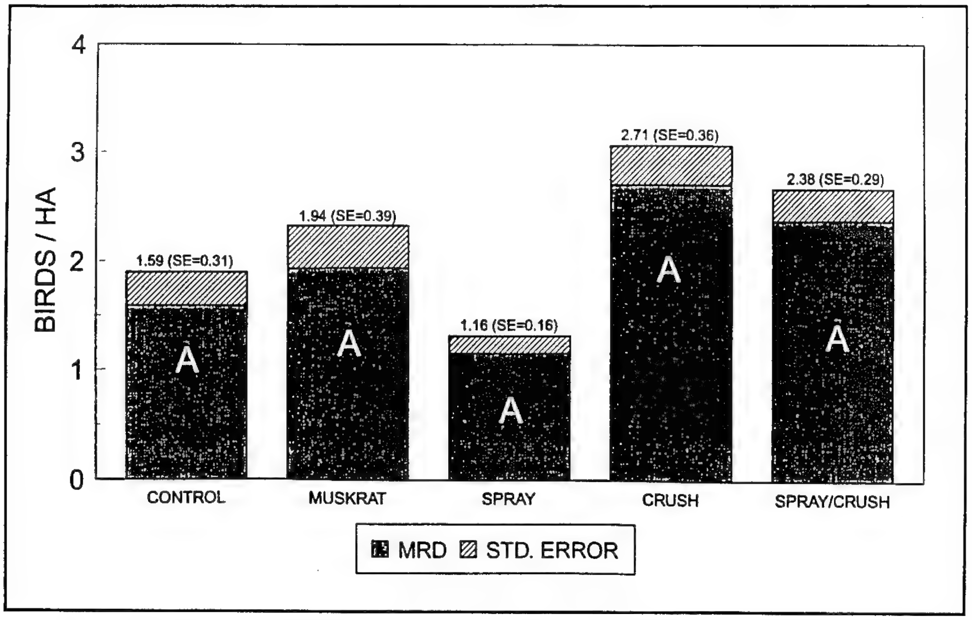

Figure 24. Mean relative density of coots in 1993 using dense cattail after manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with same letters are not significantly different ($P > 0.05$))

The MRD of red-winged blackbirds in 1993 was significantly lower in the spray/crush treatment (4 df, $P \leq 0.05$) (Figure 25). A significantly higher number of black terns were observed in the muskrat-impacted control (4 df, $P \leq 0.05$) (Figure 26). Since herons and bitterns were found at low densities in 1993, these species were pooled (Ardeidae) for analysis. A significantly higher number of Ardeidae used the crushed treatment (4 df, $P \leq 0.05$) than the other treatments or controls (Figure 27).

Redheads were the most abundant waterfowl species in 1993 with an overall MRD of 0.88 pairs/hectare (SE = 0.09). Blue-winged teal were the next most common duck with an overall MRD of 0.68 pairs/hectare (SE = 0.10) followed by mallards with an MRD of 0.36 pairs/hectare (SE = 0.09). The MRD of aggregate waterfowl pairs was significantly higher in the crushed and spray/crushed treatments than in the control and spray treatments, but was not higher than the muskrat-impacted treatment (4 df, $P \leq 0.05$) (Figure 28). Aggregate waterfowl MRD in the muskrat-impacted treatment was significantly higher than the sprayed treatment (4 df, $P \leq 0.05$) but did not differ from the control. A complete list of species and MRDs are included in Appendixes B and C.

Avian mean relative densities of controls and muskrat-impacted controls were compared between years to determine if avian densities changed between years (Tables 1 and 2). In controls, MRDs of marsh wrens and rails were significantly higher in 1992, and coots and total ducks were significantly higher in 1993 (1 df, $P \leq 0.05$) (Table 1). In muskrat-impacted controls, marsh wrens were significantly higher in 1992, and coots and yellow-headed blackbirds were more abundant in 1993 (1 df, $P \leq 0.05$) (Table 2).

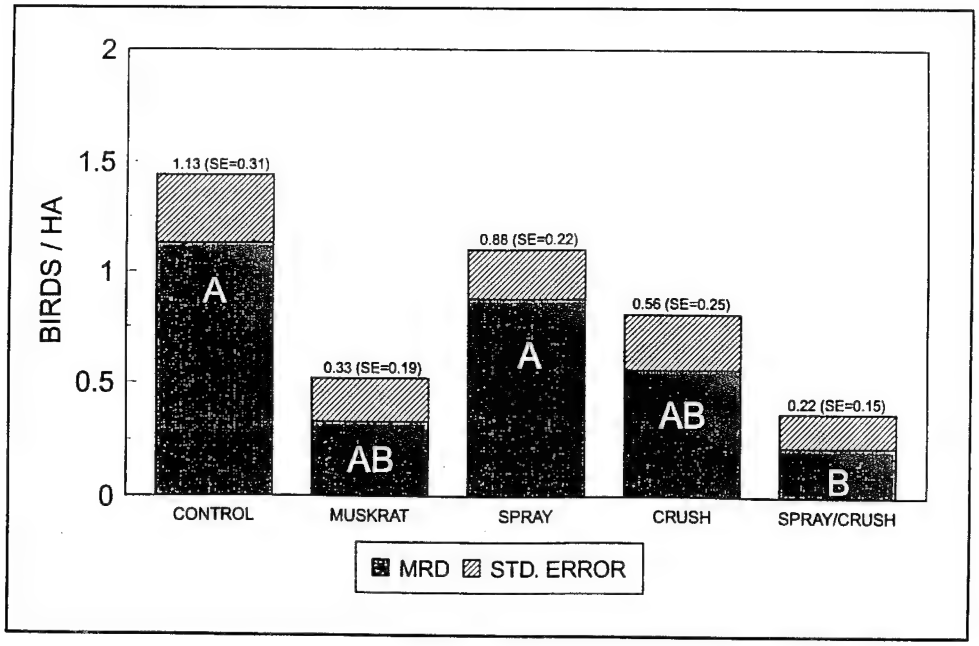

Figure 25. Mean relative density of red-winged blackbirds in 1993 using dense cattail after manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with different letters are significantly different (P < 0.04))

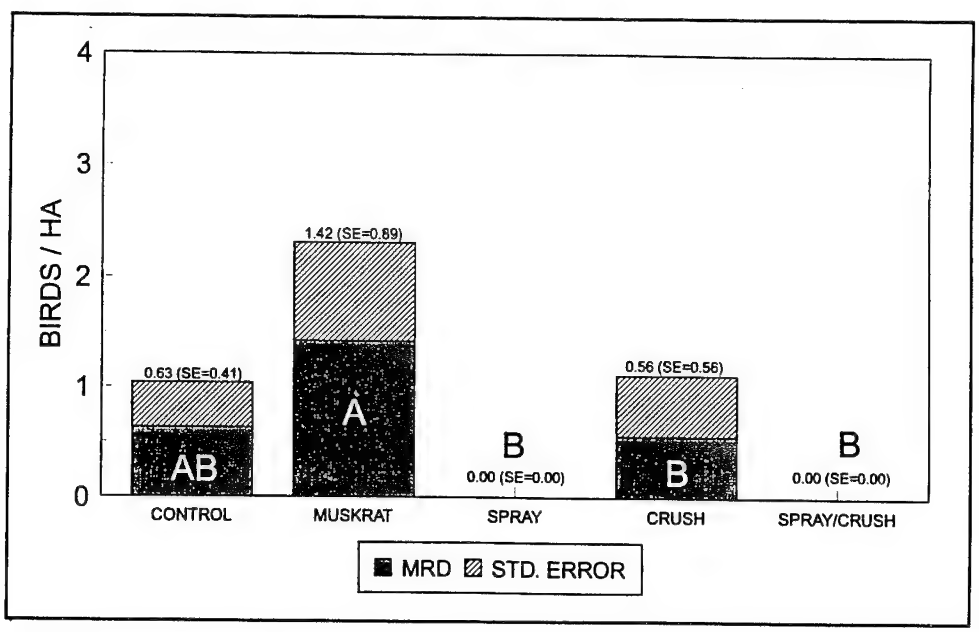

Figure 26. Mean relative density of black terns in 1993 using dense cattail after manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with different letters are significantly different (P < 0.05)

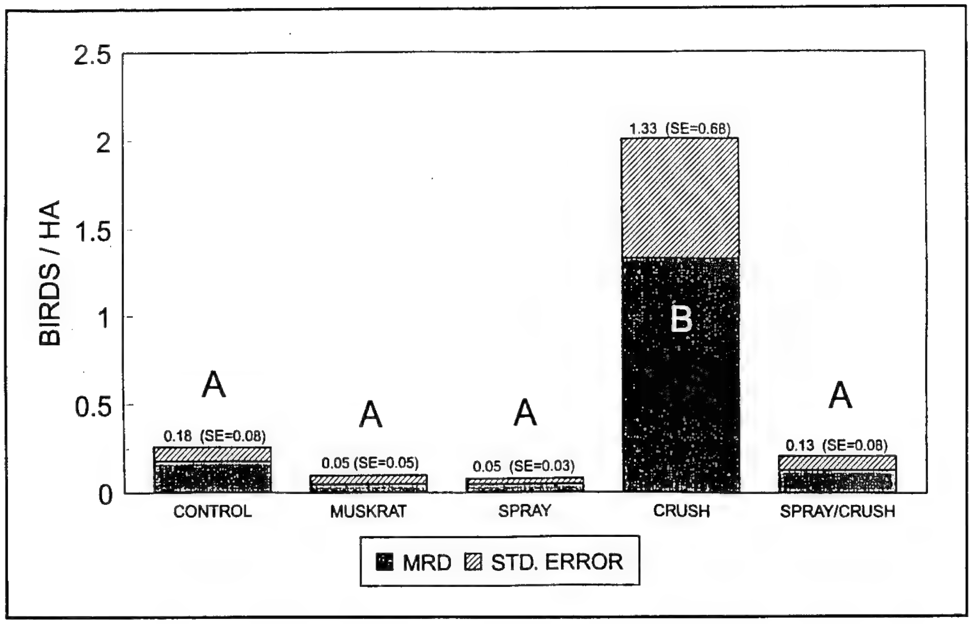

Figure 27. Mean relative density of aggregate great blue herons, great egrets, black-crowned night-herons, American bitterns, and least bitterns in 1993 using dense cattail after manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with different letters are significantly different (P < 0.05))

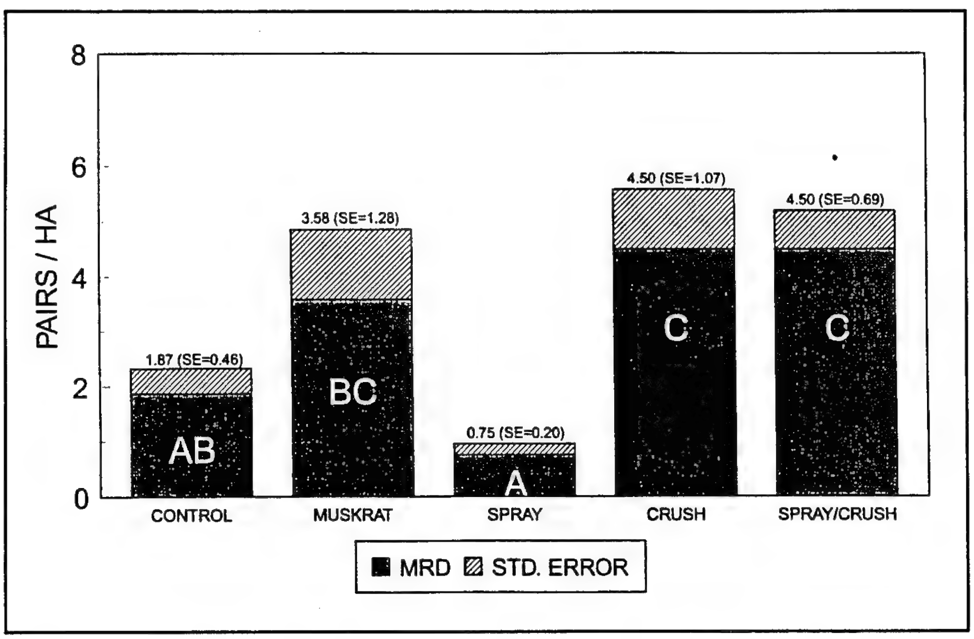

Figure 28. Mean relative density of aggregate redheads, blue-winged teal, mallards, northern shovelers, ruddy ducks, gadwalls, green-winged teal, northern pintails, and wood ducks in 1993 using dense cattail after manipulation, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with different letters are significantly different (P < 0.05))

Table 1
Comparison of Mean Relative Densities (MRD) (birds/hectare) of Avian Species During 1992 and 1993 Within Control Belt Transects at Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota

Species	1992		1993		Statistics		
	MRD	SE	MRD	SE	df	F	P
Marsh Wren	10.83	0.50	7.38	0.57	1	12.39	0.02
Yellow-Headed Blackbird	2.71	0.81	6.38	1.18	1	3.38	0.14
Red-Winged Blackbird	0.46	0.18	1.13	0.31	1	3.00	0.15
Fringe Species Group	0.83	0.33	0.54	0.23	1	0.43	0.56
American Coot	0.13	0.09	1.58	0.40	1	67.31	0.00
Aggregate Rails	0.92	0.26	0.25	0.11	1	20.70	0.01
Aggregate Herons	0.04	0.04	0.13	0.09	1	0.55	0.50
Aggregate Ducks	0.92	0.25	2.21	0.49	1	8.05	0.05

Table 2
Comparison of Mean Relative Densities (MRD) (birds/hectare) of Avian Species During 1992 and 1993 Within Muskrat-Impacted Belt Transects at Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota

Species	1992		1993		Statistics		
	MRD	SE	MRD	SE	df	F	P
Marsh Wren	12.83	0.95	9.67	0.77	1	26.67	0.01
Yellow-Headed Blackbird	2.08	0.75	8.92	1.39	1	12.94	0.02
Red-Winged Blackbird	1.92	0.97	0.33	0.19	1	6.37	0.07
Fringe Species Group	0.58	0.29	0.08	0.08	1	7.44	0.05
American Coot	0.08	0.08	1.50	0.34	1	10.38	0.03
Aggregate Rails	0.58	0.19	0.13	0.09	1	2.32	0.20
Aggregate Herons	0.25	0.25	0.00	0.00	1	1.00	0.37
Aggregate Ducks	4.75	1.86	4.00	1.45	1	0.00	1.00

Species richness in the control averaged 3.75 species/hectare (SE = 0.27) in 1992 and 4.97 species/hectare (SE = 0.27) in 1993. Species richness in the muskrat-impacted control averaged 4.81 species/hectare (SE = 0.62) in 1992 and 5.19 species/hectare (SE = 0.37) in 1993. Species richness was similar between years in both controls (1 df, $P \leq 0.05$).

In 1992, 59 percent (n = 129) of aggregate waterfowl pairs observed in dense cattail used natural openings (≥2-m-diam) (Figure 29). Approximately 11 percent of waterfowl observations were in tractor tracks, 3 percent in the transect footpath, and 1 percent in deer trails. Twenty-six percent of waterfowl observations were in dense cattail or openings <2-m diam. Seventy-six percent of waterfowl pair observations in the muskrat-impacted treatment (n = 67) were in natural openings, whereas only 8 percent of waterfowl observations in the prespray (n = 12) treatment were in natural openings.

In 1993, after cattail control, ≥88 percent of waterfowl pairs observed in the crushed (n = 119) and spray/crushed (n = 121) treatments were in the circular crushed areas (Figure 30). Less than 1 percent of duck observations in the treatments receiving crushing were seen in the Bombardier tracks outside the crushed circles. Fifty percent of waterfowl observations in the control (n = 62) were in muskrat openings, and eighty percent of the observations in the muskrat-impacted control (n = 67) were observed in natural openings. Nearly 25 percent of duck observations in the sprayed (n = 34) treatment were in tractor tracks.

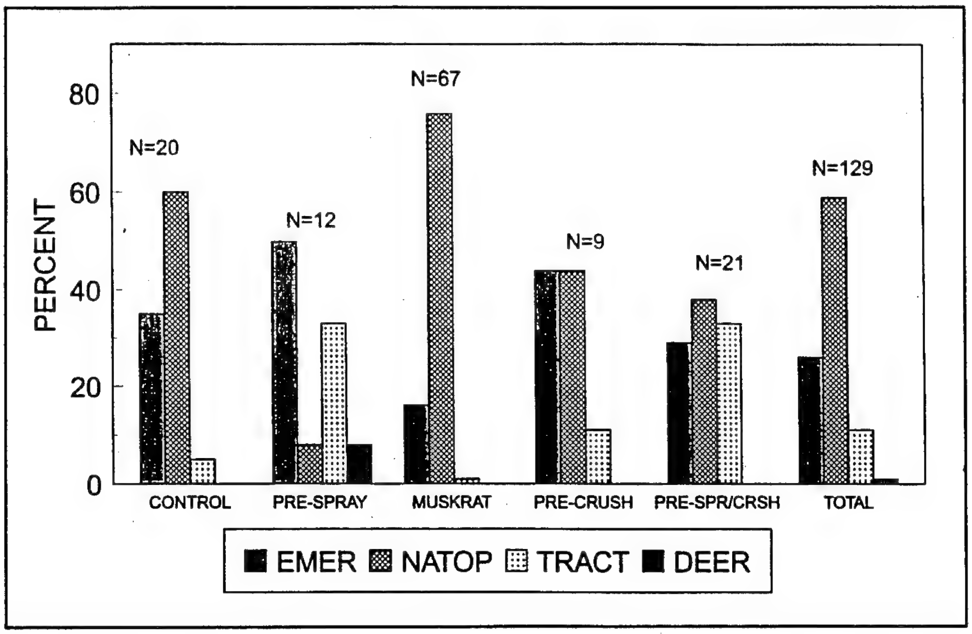

Figure 29. Percent aggregate waterfowl pair use in 1992 by open-water type prior to cattail manipulation, Mud Lake, Roberts County, South Dakota, and Traverse, County, Minnesota (EMER = dense emergents; NATOP = natural opening; TRACT = tractor tracks; DEERT = deer trail; N = total number of waterfowl pairs observed per treatment during four surveys)

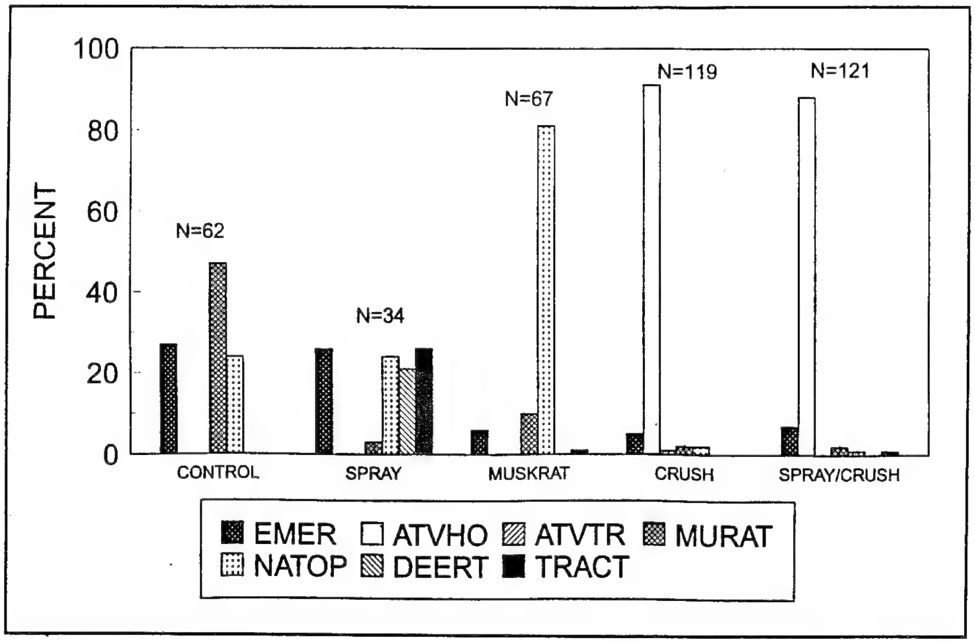

Figure 30. Percent aggregate waterfowl pair use in 1993 by open-water type prior to cattail manipulation, Mud Lake, Roberts County, South Dakota, and Traverse, County, Minnesota (EMER = dense emergents; ATVHO = ATV-crushed circle; ATVTR = ATV tracks; MURAT = muskrat-created opening; NATOP = natural opening; DEERT = deer trail; TRACT = tractor tracks; N = total number of waterfowl pairs observed per treatment during five surveys)

Muskrat Use

Spring and summer use of avian survey transects by muskrats was significantly higher in 1993 than in 1992 (1 df, $P \leq 0.001$) (Figure 31). In 1992, muskrat house density over all treatments averaged 0.01 houses/hectare (SE = 0.01) and in 1993 averaged 0.84 houses/hectare (SE = 0.10). In 1993, the number of muskrat houses in the muskrat-impacted control averaged 2.15 houses/hectare (SE = 0.36) and was significantly higher than in the control or other treatments (4 df, $P \leq 0.05$) (Figure 32). Winter muskrat use of avian survey transects was highest in the muskrat-impacted control during January 1993 and 1994 (Figure 33).

Spring Crush Treatments

Seven avian species were observed during six surveys of spring crushed and control belt transects (Appendix D). Blue-winged teal were the most abundant species with an MRD of 0.67 pairs/hectare (SE = 0.49) in the spring-crushed treatment and 0.33 pairs/hectare (SE = 0.21) in the control. The MRD of aggregate waterfowl was similar between treatments and controls (1 df, $P \geq 0.05$)

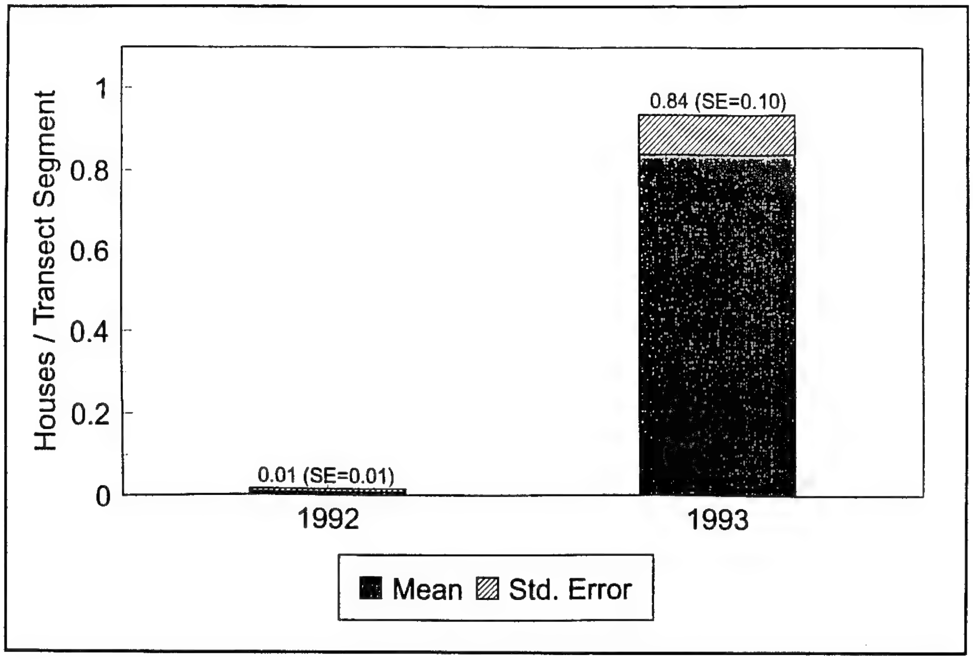

Figure 31. Mean number of muskrat houses per transect segment in 1992 and 1993 (number of houses observed in 1993 was significantly higher than in 1992 ($P < 0.0001$))

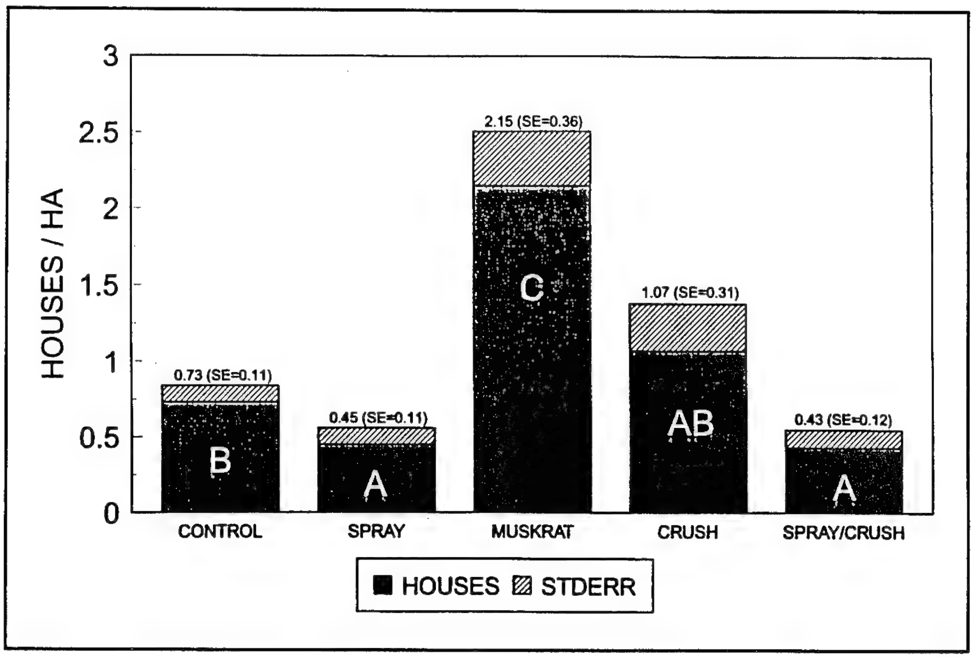

Figure 32. Mean number of muskrat houses located within avian-survey belts during May-July 1993, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (bars with different letters are statistically significant ($P < 0.05$))

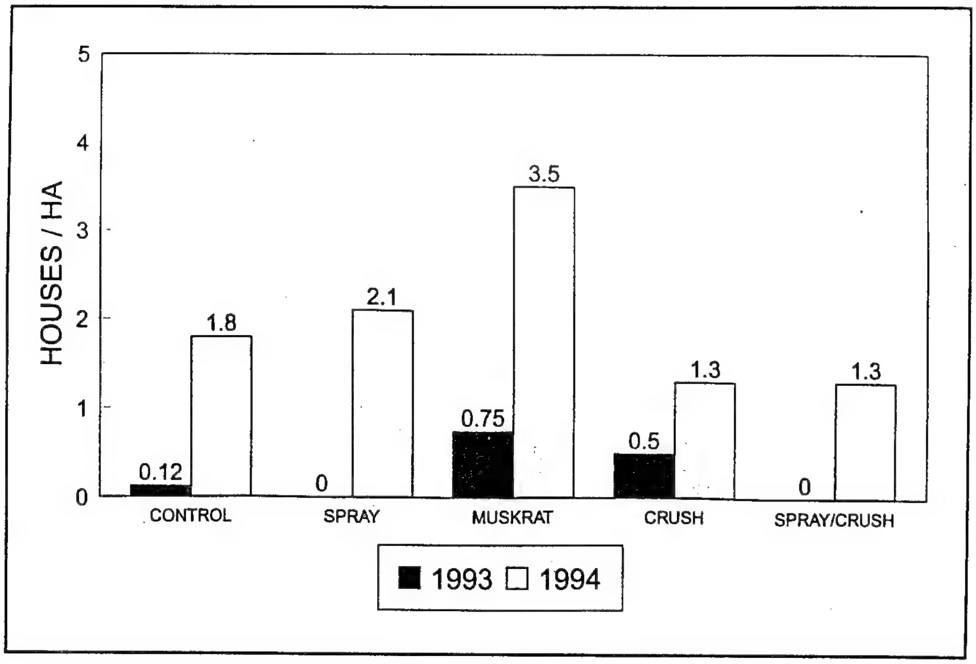

Figure 33. Mean number of muskrat houses within avian-survey belts during January 1993 and 1994, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota

(Figure 34). Several waterfowl broods were observed during avian surveys in July (Table 3). Six of eight (75 percent) broods used the crushed treatments.

Since flooding covered the tops of most emergents, vegetation could not be surveyed during the summer following manipulation. However, prior to flooding in early July, virtually no emergents had reinvaded crushed areas, whereas uncrushed portions of the crushed treatment and controls contained robust stands of emergents.

In early March, after most snow had melted and the ice had begun to break up, it was possible to take several crude vegetative measurements of standing dead vegetation in spring-crushed transects. Dead standing stem density was significantly lower in the crushed parts of the crushed treatment. Stem density averaged 0.31 stems/square meter (SE = 0.16) in the crushed areas compared with 53.9 stems/square meter (SE = 5.2) in the uncrushed areas (1 df, $P \leq 0.05$) (Figure 35). Canopy coverage of dead standing and fallen emergent stems averaged 26.7 percent in uncrushed areas and 0.6 percent in crushed areas (Figure 35). Similar vegetative measurements were planned for the winter-crushed area, but high water during the spring covered the tops of residual stems of emergents, making vegetative measurements impossible.

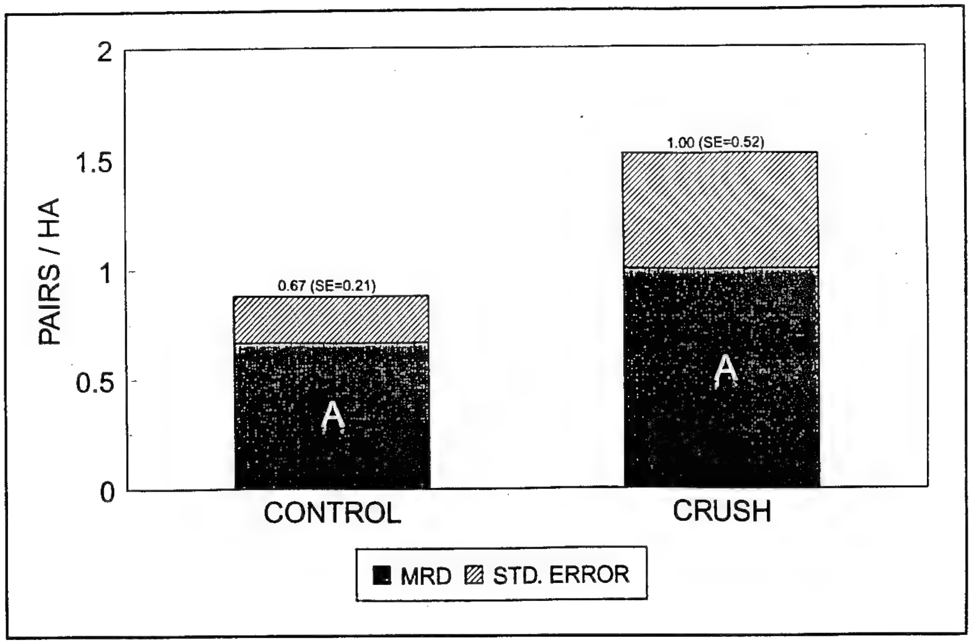

Figure 34. Mean relative density of aggregate duck pairs in 1993 following spring crushing of dense cattail, Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota (means were not significantly different ($P > 0.05$))

Table 3
Coot and Duck Broods Observed Along Spring-Crushed Treatments and Controls in 1993 at Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota

Species	Date	Treatment	Brood Size
Blue-Winged Teal	7/07/93	crush	1
Coot	7/07/93	crush	2
Blue-Winged Teal	7/22/93	control	9
Redhead	7/22/93	control	8
Redhead	7/22/93	crush	9
Redhead	7/22/93	crush	8
Blue-Winged Teal	7/22/93	crush	7
Mallard	7/22/93	crush	1

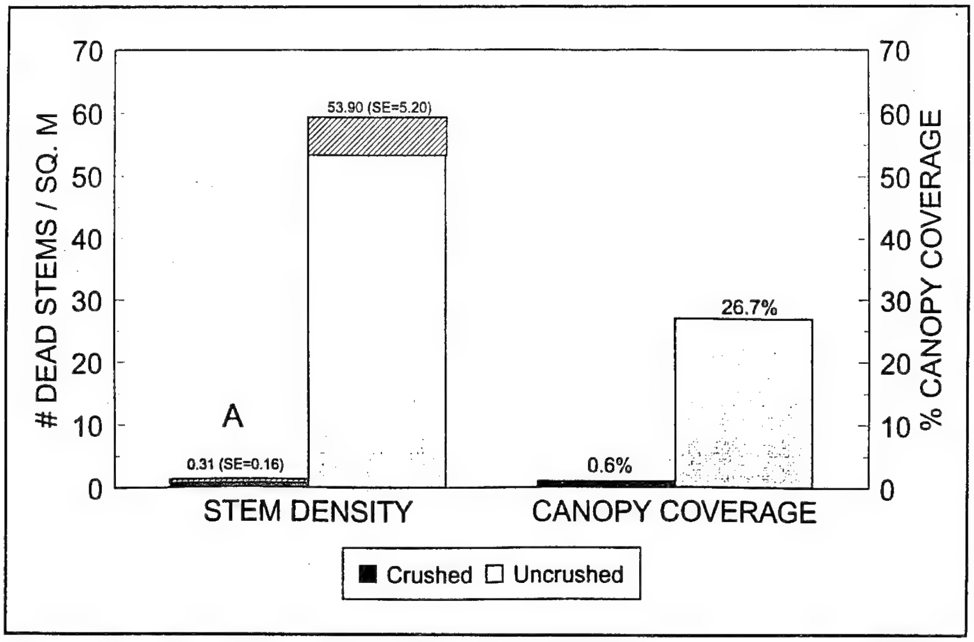

Figure 35. Standing stem density and canopy coverage of dead stems in crushed and uncrushed portions of spring-crushed transects (measurements were taken during late winter in year following crushing; bars with different letters are significantly different ($P < 0.05$))

5 Discussion

Avian Surveys

The spread of narrowleaf cattail and its hybrid throughout much of the PPR has impacted both the structure and function of many wetlands. Disturbed wetlands, such as those at Mud Lake, are particularly prone to establishment of monodominant stands of cattail.[1] Unique physiographic features and sociopolitical constraints limit the use of large-scale management alternatives at Mud Lake.

As a result, Mud Lake is best suited for small site-specific remedies to improve cattail-choked wetlands for avian species. Since Mud Lake is important to not only waterfowl but many other wetland-dependent avifauna, management should be tailored so that the potential impacts on all species are considered.

The flooding that occurred in 1993 was among the most severe ever recorded during the summer at Mud Lake. Above-average rainfall during June and July in the Lake Traverse watershed resulted in a large volume of water entering Lake Traverse. Flooding adjacent to Lake Traverse and downstream of Mud Lake made it necessary to close White Rock Dam for several weeks and use Mud Lake for floodwater storage.

By early August, water covered nearly all emergent vegetation, turning Mud Lake into a single lake-like body of water. By the end of the month, the aerial shoots of most emergents had died and had begun to decompose. The water level did not recede to normal depths until the end of September. Since field work was terminated prior to the next growing season, the impacts of the flood on the emergent plant community at Mud Lake were not evaluated.

In 1992, vegetation within avian survey belts was dominated by cattail and river bulrush. Although common cattail, narrowleaf, and hybrid cattail were all present, separation of species was not practical during the vegetation survey. However, several small nearly solid stands of common cattail were observed on drier sites, and some nearly homogenous stands of narrowleaf cattail were also present. Most of the areas surveyed appeared to contain hybrid cattail by itself or mixed with narrowleaf cattail.

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[1] Unpublished Material, 1983, H. A. Kantrud, "Mud Lake Wildlife Management Plan," U.S. Army Corps of Engineers, St. Paul, MN.

Live stem densities in 1992 were similar between the pretreatments and the control but lower in the muskrat-impacted control. The lower stem densities in the muskrat-impacted control were likely the result of recent muskrat activity. Although no active muskrat houses were observed during the summer in 1992, muskrat sign (droppings and cuttings) were evident along the transect path. Open-water areas present in the muskrat-impacted control belts were often circular, resembling openings created by past muskrat activity.

Canopy coverage was much lower in the muskrat-impacted control in 1992. However, vegetation measurements were not taken in the four muskrat-impacted control belts until early September, following an increase in water depth. As a result, the canopy-coverage estimates are likely underestimated since the higher water covered a larger percentage of dead stems than in the pretreatments of control. Nevertheless, even if canopy coverage had been taken before the change in water depth, it still likely would have been much lower than the pretreatments and control.

Although flooding prevented vegetation measurements from being taken in 1993, by early July, new aerial shoots were absent from nearly all crushed, sprayed, and spray/crushed treatments. Adjacent uncrushed and unsprayed areas contained abundant new aerial shoots. In the crushed circles, few dead standing and fallen aerial shoots from the previous year were visible at the surface of the water, whereas uncrushed areas contained abundant dead stems.

Crushed areas between the circles (Bombardier tracks) contained some new aerial shoots, but much less than adjacent uncrushed areas. Crushing in these areas was less intense; so it is likely that some stems remained above water the following spring, thus allowing some emergent stems to survive. Several crushed circles in one belt transect contained sparse new aerial shoots of cattail. Those circles with new aerial shoots were in areas where snow depth was greatest, limiting the crushing capability of the Bombardier. Again, it is likely that water did not cover the crushed stems, allowing some stems to survive.

New aerial shoots were nearly completely absent from sprayed treatments. Belt transects that were only sprayed contained numerous dead standing and fallen emergent stems. Some new aerial shoots were present near the borders of some sprayed areas. New aerial shoots in these areas were probably present because they received less spray.

In order for crushing to control cattail, crushed stems must be covered with water to prevent oxygen from reaching the rhizomes. Approximately 6 weeks of submergence is usually adequate to kill cattail. Since ice-out at Mud Lake does not typically occur until March and new aerial shoots do not emerge until May, water depths in March and April must be sufficient to cover crushed emergents.

The average water level at White Rock Pool in March and April of 1993 was above the long-term mean (Figure 5). The March water level in 1993 was approximately 30 cm above the long-term mean, with similar or higher levels achieved in only 7 of the last 50 years. The April water level was roughly 2 m

above the long-term average, and similar or higher levels were reached during 10 of the last 50 years.

Even though conditions during the spring of 1993 were ideally suited to attain emergent control, similar conditions could be achieved by slightly modifying the water regime at Mud Lake. Delaying or slowing the spring discharge of water from Mud Lake could provide sufficient water to cover crushed emergent stems during years when normal runoff is inadequate.

The higher water levels in 1993 favored semiaquatic birds since 7 of 12 species observed only in 1993 were swimming or wading birds. Overall species richness among controls did not change between years. However, a larger number of species were observed using crushed treatments in 1993. Higher species richness in crushed treatments was mainly due to increased waterfowl diversity.

Marsh wrens were the most abundant avian species using dense cattail. Marsh wrens prefer large freshwater wetlands with dense stands of narrowleaf cattail (Bent 1948) and usually nest over water at depths ranging from several to over 100 cm (Bent 1948; Leonard and Picman 1987). At Mud Lake, marsh wren densities were significantly higher in 1992 when water depths were lower. This is contrary to Leonard and Picman (1987), who reported higher marsh wren densities and increased nest success at sites with higher water levels (>1 m) and denser vegetation.

Lower marsh wren densities in 1993 may be due in part to the twofold increase in yellow-headed blackbirds. Yellow-headed blackbirds are aggressive and will exclude marsh wrens from their territories (Verner 1975; Bump 1986). Marsh wren and yellow-headed blackbird densities were negatively correlated ($r^2 = -0.37$, $P = 0.0001$) in 1993. In 1992 when yellow-headed blackbird densities were lower, no significant correlation was found ($r^2 = 0.12$, $P = 0.16$).

Crushing did not affect marsh wren density. The patchwork nature of crushing left large blocks of uncrushed cattail that were still available for nesting. Although nest success was not monitored, the risk to predation was possibly increased because of fragmentation. The tracks left by the Bombardier and the crushed circles could potentially provide travel lanes for mammalian predators and easier access by avian predators.

Higher water levels and increased interspersion from muskrats in 1993 were likely responsible for the increased densities of yellow-headed blackbirds. In 1992, water levels along avian survey transects were much lower than the 61- to 122+-cm-water depth that yellow-headed blackbirds prefer (Bent 1958), but in 1993, water depths were near optimal. In addition, yellow-headed blackbirds that used deeper marshes elsewhere at Mud Lake in 1992 were displaced from these areas in 1993 because high water limited the availability of nesting material (personal observation of the senior author).

There were no significant differences in yellow-headed blackbird densities between treatments and controls in 1992 or 1993. Weller and Fredrickson

(1974) observed that yellow-headed blackbird densities increased as percentage of open water increased and peaked at 70-percent open water. This did not appear to be the case at Mud Lake since the MRD was not higher in muskrat-impacted controls or crushed treatments where the percentage of open water was higher.

It is possible that the percentage of open water was not great enough in either the muskrat-impacted control or the crushed treatments to cause a significant increase in the MRD of yellow-headed blackbirds. In addition, higher water levels and increased muskrat activity in 1993 in all treatments elevated the percentage of open water and may have obscured differences that would have been evident under ordinary conditions.

Red-winged blackbird densities remained relatively unchanged during the 2 years of the study. Red-winged blackbirds use a much broader range of habitat types for nesting than yellow-headed blackbirds, nesting over both dry land and water (Weller and Spatcher 1965; Miller 1968). As a result, red-winged blackbirds are less easily influenced by water level changes and muskrat activity (Weller and Fredrickson 1974).

At Mud Lake, red-winged blackbirds were most often observed on the periphery of cattail stands or on drier sites within dense emergents. Since breeding territories of red-winged blackbirds and yellow-headed blackbirds are mutually exclusive (Weller and Spatcher 1965), red-winged blackbirds are rarely observed in the deeper marsh if occupied by yellow-headed blackbirds.

In 1992, red-winged blackbird densities were similar between controls and pretreatments. However, in 1993, the density of red-winged blackbirds in the spray-crushed treatment was significantly lower than control and sprayed treatments. The lower density of red-winged blackbirds in the spray/crush treatment is puzzling since similar reductions in MRD were not observed in the sprayed or crushed only treatments.

Perhaps the combination of crushing and spraying reduced nesting cover to a greater extent than either treatment alone. Even though both sprayed and spray/crushed areas lacked new aerial shoots that provide nesting cover, spray/crush areas likely had the least amount of nesting cover.

Common yellowthroats, song sparrows, and brown-headed cowbirds comprised >90 percent of the FSG. Both common yellowthroats and song sparrows use wetland margins. Song sparrows prefer nesting in areas near water such as cattail marshes (Bent 1968), and common yellowthroats often nest on the borders of large wetlands and small islands in marshes (Bent 1953). Brown-headed cowbirds are obligate brood parasites but occupy specific undefended ranges (Darley 1982). Common yellowthroats and song sparrows are two of the most frequent hosts of brown-headed cowbirds (Terres 1980). During both years of the study, these three species were most often observed in phragmites and trees near the periphery of the transect belt.

Little has been reported in the literature on how interspersion affects density of species that use the periphery of dense emergents. It appears that increased interspersion has little affect on MRDs of FSG. However, if nesting densities of common yellowthroats and song sparrows remain the same in muskrat-impacted and crushed areas, parasitism by cowbirds could potentially increase. Cowbirds locate potential hosts by watching nest-building by hosts (Hann 1941; Norman and Robertson 1975). Increased interspersion from muskrats or mechanical crushing may benefit cowbirds by allowing host nests to be more easily detected.

The higher water levels in 1993 were probably most responsible for significantly lower MRD of aggregate rails. Both soras and Virginia rails prefer shallow to intermediate water depths (≤40 cm) (Rundle and Fredrickson 1981; Johnson and Dinsmore 1986). Both species of rails appeared to make greater use of shallower sites adjacent to avian survey transects in 1993. During May and early June, numerous rails were seen and heard in flooded reed canary grass (*Phalaris arundinacea*) outside of avian survey transects. Most of these sites contained little or no water in 1992 and probably received little use then by rails.

The MRD of aggregate rails was not significantly affected by spraying or crushing. Since sprayed areas contained a large proportion of dead standing emergents (>85 percent), rails probably had adequate vegetative cover. Crushing may have even benefited rails by improving mobility within dense emergents. On several occasions, rails were observed in the Bombardier tracks or on the edge of the crushed circle walking on crushed vegetation. During both years of the study, both sora and Virginia rails were observed walking short distances in the foot path in the center of the belt.

The increase in abundance of American coots in 1993 was probably due both to an increase in water depth and interspersion. Coots prefer semipermanent wetlands (Kantrud 1985) and reach their highest densities in well-flooded marshes with a 50:50 ratio of open water and emergents (Weller and Fredrickson 1974). Coots often avoid nesting in emergents with low water levels (Gorenzel, Ryder, and Braun 1981) and select wetlands that have a low probability of becoming dry during the nesting and brood-rearing period (Sutherland and Maher 1987).

Coots may have moved to denser cattail when high water levels reduced nesting cover in White Rock Pool. In 1993, noticeably less dead fallen litter was present within all belt transects because of the higher water levels. Since coots usually swim rather than fly when moving within a wetland, the prevalence of fallen litter in 1992 would have acted as an impediment to movement.

The MRD of coots in 1993 was not significantly higher in the crushed treatments where interspersion was higher. The lack of a statistical difference may have been partly due to reduced differentiation between treatments and controls because of higher water depths and increased muskrat activity. Furthermore, many coots were forced to use shallower wetlands with denser emergents in 1993 because higher water levels in White Rock Pool and along level ditches reduced coot habitat there. Thus many coots could have been forced to use less preferred habitat.

Despite higher water levels in 1993, the MRD of aggregate herons was not significantly different between years. The Ardeidae group was comprised of >80-percent great blue herons and black-crowned night herons in 1993. Neither species nested within avian survey transects, but nesting colonies were present near Mud Lake.

In 1993, a significantly higher number of total Ardeidae used the crushed treatment. Herons using the crushed treatment were seen foraging on rough fish that had moved into shallower wetlands from White Rock Pool and level ditches following flooding. It is unclear why herons did not similarly use the spray/crushed treatment. However, several of the crushed belt transects were near a flooded gravel levy that was used by herons as a loafing site, and this may have influenced selection of a foraging site.

Higher water levels and increased muskrat activity both contributed to the increase in black terns in 1993. The greatest number of black terns were observed in the muskrat-impacted control where muskrat house density was highest. Black terns are semicolonial nesters and often build nests and raise their young on muskrat feeding platforms or degraded muskrat houses. Although several nests were initiated within the survey belts, all nests were eventually inundated by floodwaters, and no chicks were known to fledge. The lack of black terns in the two sprayed treatments was probably due to a lack of suitable nesting sites.

The higher number of waterfowl using controls in 1993 compared with 1992 was likely due to increased water depth and interspersion. With the exception of mallards, the MRDs of every waterfowl species observed in 1992 either increased or stayed the same in 1993. The largest increases were by redheads and ruddy ducks, both of which prefer deeper hemimarsh (Weller and Spatcher 1965; Weller and Fredrickson 1974). A similar increase was not seen in the muskrat-impacted control where waterfowl densities were similar during both years.

The number of waterfowl pairs observed in White Rock Pool and along level ditches during mid-May was significantly lower in 1993. Higher water depths may have caused waterfowl to use shallower wetlands where emergent vegetation was denser and food more available. The shallower wetlands would have provided the necessary isolation of pairs from conspecifics (Murkin, Kaminski, and Titman 1982) and an increased availability of invertebrates (Murkin and Kadlec 1986).

In 1992, the MRD of aggregate waterfowl pairs was not higher in the muskrat-impacted control even though stem densities were lower and interspersion was greater. However, interspersion in the muskrat-impacted control was much lower than the 50:50 ratio of open water to emergents that waterfowl prefer (Weller and Spatcher 1965; Murkin, Kaminski, and Titman 1982). The small sample size for the muskrat-impacted control made potential differences difficult to detect.

The use of hemimarsh by waterfowl has been well documented (Weller and Spatcher 1965; Weller and Fredrickson 1974; Murkin, Kaminski, and Titman 1982). In 1993, waterfowl preferred the crushed and spray/crush treatments over the control and sprayed treatment. The openings made by crushing were similar in size to natural openings made around lodges by muskrats. In 1992, waterfowl were frequently observed using openings created by muskrats in White Rock Pool and along level ditches.

Waterfowl using crushed areas were observed engaging in a variety of behaviors including feeding, resting, and courtship. Blue-winged teal and redheads were seen foraging on snails (Limnaedae), which were abundant during both years of the study. Snails and presumably other invertebrates were gleaned from emergent litter near the surface of the water.

Although avian surveys were only conducted during the morning, waterfowl were also observed using the crushed areas during the afternoon for loafing and were seen flying into crushed circles shortly after sunset. On several occasions, blue-winged teal, redheads, mallards, and other species were observed flying to crushed openings after being disturbed. Redheads and ruddy ducks were observed using the crushed Bombardier path to move between crushed circles.

Spraying in combination with crushing did not result in increased waterfowl use over crushing alone. Since residual emergent stems remained following spraying, most waterfowl use was restricted to openings created by crushing. Areas that were sprayed only were used little by waterfowl. Again, the presence of a large number of dead standing and fallen litter probably prevented waterfowl pairs from using these areas.

Since reinvasion of cattail can occur in 4 years or less, depending on water depth (Solberg 1989), crushing sprayed areas would be recommended to maximize the benefits of spraying to waterfowl. However, spraying would only be recommended over crushing in those cases when it is not possible to cover crushed stems with water or if treatment is needed over a large or inaccessible area.

The size (Weller 1975) and distribution (Kaminski and Prince 1984) of artificial openings are important factors that govern waterfowl use. Crushing has the advantage of allowing for greater flexibility in the application of the treatment. Kaminski and Prince (1984) suggested that openings made in sinuous strips may be effective in maximizing the number of waterfowl pairs using a treated area. Weller (1975) felt aerial herbicide application by helicopter would be better than fixed-wing aircraft for producing interspersion; however, cost is prohibitive for most areas.

Spring crushing was effective in killing emergents, even though crushing was not done when total nonstructural carbohydrates were at their lowest as Linde, Janisch, and Smith (1976) suggested. Rather, crushing was done when water levels had dropped sufficiently to allow access by the Bombardier. Virtually no live or dead stems were present in circles following crushing, and no new live stems reinvaded.

Waterfowl use, however, was not significantly higher following crushing, although sample size was small. It is possible that spring crushing occurred too late in the breeding season to benefit breeding pairs of waterfowl. Also, the smaller size of the spring-crushed openings may have affected waterfowl pair use. Several broods of ducks used spring-crushed circles, although the sample size was too small for analysis.

The Bombardier was used in water up to 80 cm and did not bog down in the mud. Waves created by the back-and-forth motion of the Bombardier windrowed vegetation along the perimeter of the circle leaving the crushed area mostly free of vegetation. The water depth in the center of each circle increased by 30 to 50 cm following crushing.

Conclusions and Management Recommendations

Results from this study show that winter crushing can effectively control dense emergents and significantly increase waterfowl, coot, and heron densities while having little effect on other avifauna. To make large continuous stands of cattail and other dense emergents at Mud Lake available to waterfowl, it is recommended that a management regime incorporating crushing be started. However, winter crushing should only be done when water levels during the spring will be adequate to cover crushed areas for 6 weeks or more during the spring.

The size of crushed areas should be approximately 10 to 15 m in diameter or roughly the same size as openings created by muskrats around winter lodges. Openings should be spaced at least 25 m apart and connected by crushing a path between openings. An alternating pattern similar to the one used for this study would be suitable. Although spraying is effective in controlling cattail, crushing is recommended over spraying or spraying and crushing.

Crushing cattail at Mud Lake has several advantages over spraying. Since a Bombardier is available at Mud Lake, crushing is likely more cost-effective. Crushing has the advantage of making treated areas immediately available to waterfowl the following spring. Crushing can also leave a significant portion of an area with dead standing emergents, providing better interspersion for waterfowl without significantly impacting winter cover for pheasants and white-tailed deer.

The time frame available for winter crushing is larger than for spraying and is less likely to be affected by adverse weather. Crushing also offers the manager greater flexibility for treating small areas and is less likely to impact nontarget areas such as nearby agricultural fields.

When water levels are near normal at Mud Lake, muskrats sparsely use dense cattail and provide little benefit to waterfowl. At above-normal water levels, muskrats will move from deeper marshes to areas of dense cattail where they will help to create hemimarsh conditions that waterfowl prefer. Crushing may aid dispersal of muskrats into areas of dense cattail by providing emigration

routes. When possible, crushed travel lanes from areas of high muskrat abundance (i.e., White Rock Pool and along level ditching) to crushed areas should be constructed.

Although spring crushing was effective in controlling cattail, its potential for immediately increasing waterfowl pair use is still unclear. Spring crushing may serve as an alternative to winter crushing when spring water levels are not sufficient to cover winter-crushed stems.

Fall crushing may also be effective in controlling cattail and would probably result in better compaction than crushing over the ice. Tire tracks made by a tractor in late fall during both years of the study created openings that were used by waterfowl. Crushing during the summer is not recommended particularly if water levels are low unless areas are crushed repeatedly to kill new stems that may sprout after the initial treatment.

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Appendix A Species List and Rank of Abundance[1]

Common Name	Scientific Name	Rank	
		1992	1993
Marsh Wren	*Cistothorus palustris*	1	1
Yellow-Headed Blackbird	*Xanthocephalus xanthocephalus*	2	2
Red-Winged Blackbird	*Agelaius phoenicius*	3	6
Blue-Winged Teal	*Anas discors*	4	5
Sora	*Porzano carolina*	5	8
Mallard	*Anas platyrhynchos*	6	7
Virginia Rail	*Rallus limicola*	7	15
Common Yellowthroat	*Geothlypis trichas*	8	11
Song Sparrow	*Melospiza melodia*	9	17
Gadwall	*Anas strepera*	10	13
Redhead	*Aythya americana*	11	4
Brown-Headed Cowbird	*Molothrus ater*	12	17
Great Egret	*Casmerodius albus*	13	—
Wood Duck	*Aix sponsa*	14	21
American Coot	*Fulica americana*	15	3
Northern Shoveler	*Anas clypeata*	16	9
Swamp Sparrow	*Melospiza georgiana*	17	23

(Continued)

[1] Data for birds reported on avian surveys in 1992 and 1993 at Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota.

Common Name	Scientific Name	Rank	
		1992	1993
Ring-Necked Pheasant	*Phasianus colchicus*	18	—
Sedge Wren	*Cistothorus platensis*	18	—
Green-Winged Teal	*Anas crecca*	20	20
Black Tern	*Chlidonias niger*	—	10
Ruddy Duck	*Oxyura jamaicensis*	—	12
Black-Crowned Night Heron	*Nycticorax nycticorax*	—	14
Great Blue Heron	*Ardea herodias*	—	15
American Bittern	*Botaurus lentiginosus*	—	16
Least Bittern	*Ixobrychus exilis*	—	19
Northern Pintail	*Anas acuta*	—	21
Northern Harrier	*Circus cyaneus*	—	23
Eared Grebe	*Podiceps nigricollis*	—	23
Pied-Billed Grebe	*Podilymbus podiceps*	—	23
Canada Goose	*Branta canadensis*	—	23
Killdear	*Charadrius vociferus*	—	28
Mourning Dove	*Zenaida macroura*	—	28
Horned Lark	*Eremophila alpestris*	—	28

Appendix B
Mean Relative Densities (MRD) (birds/hectare) Using Dense Cattail Prior to Manipulation[1]

Species	Control		Muskrat-Impacted		Prespray		Precrush		Prespray/ precrush		Overall	
	MRD	SE	MRD	SE	MRD	SE	MRD	SE	MRD	SE	MRD	SE
Marsh Wren	8.75	0.51	11.60	0.80	10.20	0.75	9.83	0.56	8.61	0.62	9.65	0.30
Yellow-Headed Blackbird	1.12	0.41	1.42	0.40	1.00	0.49	1.33	0.59	2.33	0.64	1.40	0.23
Red-Winged Blackbird	0.46	0.18	1.92	0.97	0.46	0.23	0.94	0.72	0.39	0.18	0.72	0.20
Sora	0.46	0.12	0.50	0.19	0.42	0.13	0.89	0.24	0.44	0.18	0.53	0.75
Virginia Rail	0.46	0.19	0.08	0.08	0.25	0.14	0.44	0.17	0.11	0.08	0.29	0.07
Common Yellowthroat	0.17	0.08	0.50	0.17	0.33	0.14	0.22	0.13	0.29	0.06	0.29	0.06
Song Sparrow	0.29	0.09	0.12	0.07	0.28	0.13	0.06	0.06	0.20	0.04	0.20	0.04
Brown-Headed Cowbird	0.16	0.10	0.04	0.04	0.00	0.00	0.11	0.08	0.08	0.03	0.08	0.03
Blue-Winged Teal	0.38	0.12	0.92	0.34	0.14	0.10	0.22	0.13	0.62	0.23	0.42	0.28
Mallard	0.00	0.00	0.33	0.19	0.14	0.10	0.22	0.13	0.14	0.08	0.15	0.04
Gadwall	0.13	0.07	0.50	0.34	0.05	0.05	0.00	0.00	0.14	0.08	0.14	0.05
Redhead	0.13	0.19	0.17	0.11	0.05	0.05	0.11	0.11	0.10	0.07	0.10	0.04
Wood Duck	0.00	0.00	0.42	0.29	0.00	0.00	0.00	0.00	0.05	0.05	0.06	0.04
Northern Shoveler	0.00	0.00	0.17	0.11	0.00	0.00	0.00	0.00	0.05	0.05	0.03	0.02
Green-Winged Teal	0.00	0.00	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01

[1] MRD of fifteen species of birds using dense cattail in 1992 prior to manipulation at Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota.

Appendix C
Mean Relative Densities (birds/hectare) Using Dense Cattail Following Manipulation[1]

Species	Control		Muskrat-Impacted		Spray		Crush		Spray/Crush	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Y-H Blackbird	8.12	1.54	11.00	1.52	5.56	1.00	7.67	1.16	6.92	1.61
Marsh Wren	7.62	0.78	9.25	0.64	8.19	0.70	7.00	0.90	6.42	0.88
R-W Blackbird	1.12	0.31	0.33	0.19	0.88	0.22	0.55	0.25	0.22	0.15
Brown-Headed Cowbird	0.04	0.04	0.08	0.08	0.00	0.00	0.11	0.11	0.00	0.00
Song Sparrow	0.00	0.00	0.00	0.00	0.08	0.06	0.00	0.00	0.00	0.00
Common Yellowthroat	0.29	0.11	0.00	0.00	0.29	0.09	0.00	0.00	0.22	0.17
American Coot	1.60	0.31	1.94	0.39	1.16	0.16	2.71	0.36	2.38	0.29
Sora	0.17	0.10	0.17	0.11	0.04	0.04	0.17	0.09	0.22	0.10
Virginia Rail	0.08	0.06	0.00	0.00	0.00	0.00	0.11	0.08	0.11	0.08
Great Blue Heron	0.00	0.00	0.00	0.00	0.03	0.03	0.50	0.28	0.03	0.03
Great Egret	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.00	0.00
B-C Night Heron	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.36	0.00	0.00
American Bittern	0.08	0.05	0.00	0.00	0.03	0.03	0.10	0.03	0.07	0.04
Least Bittern	0.10	0.06	0.05	0.05	0.00	0.00	0.00	0.00	0.03	0.03
Redhead	0.58	0.19	0.75	0.28	0.79	0.19	1.28	0.35	1.56	0.30
Blue-Winged Teal	0.50	0.17	1.00	0.52	0.04	0.04	1.20	0.31	1.56	0.36
Mallard	0.25	0.21	1.25	0.82	0.04	0.04	0.33	0.16	1.06	0.32
Northern Shoveler	0.42	0.24	0.17	0.11	0.04	0.04	1.17	0.60	0.50	0.18

(Continued)

[1] MRD of twenty-three species of birds using dense cattail in 1993 following manipulation at Mud Lake, Roberts County, South Dakota, and Traverse County, Minnesota.

Species	Control		Muskrat-Impacted		Spray		Crush		Spray/Crush	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Ruddy Duck	0.38	0.13	0.25	0.13	0.04	0.04	0.50	0.32	0.06	0.06
Gadwall	0.08	0.06	0.08	0.08	0.04	0.04	0.22	0.10	0.22	0.13
Green-Winged Teal	0.00	0.00	0.33	0.19	0.00	0.00	0.00	0.00	0.06	0.06
Northern Pintail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.08
Wood Duck	0.00	0.00	0.08	0.08	0.00	0.00	0.11	0.11	0.00	0.00

Appendix D
Mean Relative Densities (birds/hectare) Using Dense Cattail Following Spring Crushing[1]

Species	Control		Crush	
	MRD	SE	MRD	SE
American Bittern	0.17	0.17	0.00	0.00
Great Blue Heron	0.17	0.17	0.00	0.00
American Coot	0.17	0.17	0.33	0.21
Blue-Winged Teal	0.33	0.21	0.67	0.49
Northern Shoveler	0.17	0.17	0.00	0.00
Wood Duck	0.00	0.00	0.33	0.33
Redhead	0.17	0.17	0.00	0.00
Note: Ducks are pairs; other species are individuals.				

[1] MRD of seven species of birds using dense cattail in 1993 following spring crushing at Mud Lake, Roberts County, South Dakota, and Traverse County, Minesota.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1.AGENCY USE ONLY ***(Leave blank)***

2.REPORT DATE
December 1995

3.REPORT TYPE AND DATES COVERED
Final report

4.TITLE AND SUBTITLE
Avian Responses to Chemically and Physically Manipulated Cattail Stands in a Northern Prairie Marsh

5.FUNDING NUMBERS

6.AUTHOR(S)
Mark J. Humpert, Daniel E. Hubbard, Kent C. Jensen

7.PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Wildlife and Fisheries Sciences,
South Dakota State University, Brookings, SD 57001;
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8.PERFORMING ORGANIZATION REPORT NUMBER
Technical Report
WRP-SM-17

9.SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers
Washington, DC 20314-1000

10.SPONSORING/MONITORING AGENCY REPORT NUMBER

11.SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a.DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b.DISTRIBUTION CODE

13.ABSTRACT ***(Maximum 200 words)***

Many wetlands in the Prairie Pothole Region have been invaded by narrow-leaf cattail (*Typha angustifolia*) and its hybrid (*T. X glauca*), forming dense monodominant stands. Waterfowl and many other wetland-dependent birds prefer wetlands with approximately a 50:50 mix of vegetation and open water (hemimarsh). To create hemimarsh conditions, *Typha*-dominated cattail stands were sprayed with glyphosate, cattail was winter crushed with a Bombardier all-terrain vehicle, and cattail was both sprayed and winter-crushed. Two control treatments were used: (a) cattail impacted naturally by muskrats (*Ondatra zibethica*) and (b) unmanipulated cattail. Mean relative densities (MRD) of passerines and most other non-Anatidae did not differ significantly between treatments or the two controls ($P \geq 0.05$). The MRD of aggregate waterfowl pairs were significantly higher in crushed and spray/crushed stands of cattail compared with sprayed or unmanipulated cattail ($P = 0.006$). The MRD of aggregate waterfowl pairs were intermediate in cattail stands impacted naturally by muskrats. Ardeidae use was significantly higher in crushed cattail ($P = 0.003$). Prior to cattail manipulation, most waterfowl use (59 percent) was associated with natural openings (≥ 2-m diam) in cattail. After manipulation, ≥88 percent of waterfowl observations in the crushed and spray/crushed treatments were in the crushed areas, and 47 percent

(Continued)

14.SUBJECT TERMS

Aquatic herbicide	Habitat selection	Waterfowl
Avian habitat	Marsh management	
Cattail	Muskrats	

15.NUMBER OF PAGES
68

16.PRICE CODE

17.SECURITY CLASSIFICATION OF REPORT	18.SECURITY CLASSIFICATION OF THIS PAGE	19.SECURITY CLASSIFICATION OF ABSTRACT	20.LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

13. (Concluded).

of observations in the control were in openings created by muskrats. Species richness was significantly higher in crushed and spray/crushed treatments, primarily because of increased waterfowl diversity. Stem density of emergents prior to cattail manipulation averaged 48.2 stems/square meter in the muskrat-impacted control and 61.8 stems/square meter in the pretreatments and control. Vegetation measurements could not be taken during the summer following manipulation because of severe flooding. However, cattail had not reinvaded the sprayed, sprayed/crushed, or crushed areas by July 1, just prior to flooding. Muskrats made little use of dense cattail during the first year but increased substantially in the second year, primarily because of higher water depths. Two additional areas containing dense river bulrush (*Scirpus fluviatilis*) and cattail were crushed during the spring. The MRD of aggregate waterfowl pairs were not significantly different between crushed areas and controls $P = 0.76$), but sample size was small. Six of eight waterfowl broods observed in the spring-crushed treatments and controls used the spring-crushed treatment. The number of dead, standing stems, measured the following winter, was significantly lower in the crushed treatments ($P \leq 0.05$). When spring water level is sufficient, winter crushing of dense cattail can significantly increase waterfowl pair use and control cattail while having little effect on most passerines and other non-Anatidae. Crushing should be used in combination with or as an alternative to spraying. Spring crushing can control cattail if spring water depth is adequate, but its effects on waterfowl are unclear.